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(NASA-TM-X-74197) GOALS AND OBJECTIVES FOR AMERICA'S NEXT DECADE IN SPACE (National Aeronautics and Space Administration) 109 p

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FOREWORD

In February of 1969, President Nixon established a Space Task Group to provide a "definitive recommendation on the direction which the U. S. space program should take in the post-Apollo period." As one of its contributions to the Space Task Group, the National Aeronautics and Space Administration prepared a report entitled "America's Next Decades in Space". That report stressed the program approaches necessary to move toward selected goals and objectives of the space program at different reasonable rates. Those goals and objectives were abstracted from previously developed material which, together with statements of values inherent in pursuit of space program activities, are published herein. This report therefore serves as a complement to "America's Next Decades in Space".

This report is organized by program category, each category being a logical grouping of program activities by scientific or technological discipline. Within each category, the long-term, unchanging goals, are enunciated; these are the basic reasons for undertaking program activities. In pursuit of the goals, there are broad and specific objectives, or defined steps, laid out as the major organizers of program activity. For each category, either achievements or capabilities are defined which the United States could reach within fifteen to twenty years were energy and resources applied; these achievements or capabilities represent the kinds of valuable returns foreseen from space activities.

September, 1969

INTRODUCTION

During the past decade the United States developed a space program that encompassed a broad spectrum of activities. In the decade ahead we look forward to building on the experience of this past decade in order to develop new capabilities in space that can and will be used for the benefit of mankind and for further exploration into the unknown depths of space.

Such a space program would serve a broad range of national purposes; scientific, technical, economic, social, and political, and would further the goals and objectives set forth in the National Aeronautics and Space Act of 1958:

"The Congress hereby declares that it is the policy of the United States that activities in space should be devoted to peaceful purposes for the benefit of all mankind."

"The aeronautical and space activities of the United States shall be conducted so as to contribute materially to one or more of the following objectives:

(1) The expansion of human knowledge of phenomena in the atmosphere and space;

(2) The improvement of the usefulness, performance, speed, safety, and efficiency of aeronautical and space vehicles;

(3) The development and operation of vehicles capable of carrying instruments, equipment, supplies, and living organisms through space;

(4) The establishment of long-range studies of the potential benefits to be gained from the opportunities for, and the problems involved in the utilization of aeronautical and space activities for peaceful and scientific purposes;

(5) The preservation of the role of the United States as a leader in aeronautical and space science and technology and in the application thereof to the conduct of peaceful activities within and outside the atmosphere;

(6) The making available to agencies directly concerned with national defense of discoveries that have military value or significance, and the furnishing by such agencies, to the civilian agency established to direct and control nonmilitary aeronautical and space activities, of information as to discoveries which have value or significance to that agency;

(7) Cooperation by the United States with other nations and groups of nations in work done pursuant to this Act and in the peaceful application of the results thereof; and

(8) The most effective utilization of the scientific and engineering resources of the United States, with close cooperation among all interested agencies of the United States in order to avoid unnecessary duplication of effort, facilities, and equipment."

The Act itself and its legislative history also made perfectly clear the strong intent of the Congress that the core of the United States space effort would be an open civilian program that all the world could see was indeed "devoted to peaceful purposes for the benefit of all mankind", a decision that has time and again proven of great value to us on the international scene.

These goals and purposes, which were established at the beginning of the Space Age, are as valid and worthwhile today as they were when first enunciated. They continue today as the general expression of our aims in space, and just as they underlay our decisions and program choices during the past decade, so must they underlie our decisions and choices for the next decade.

However, in order to formulate a specific national space program, the national goals set forth in the National Aeronautics and Space Act must be translated into action type goals and objectives that correspond to potential capabilities, explicit needs, and opportunities of the future. Accordingly, three broad goals have been identified for future activities in space.

- To have the capability of operating in and exploring space.

- To apply space capabilities for direct and identifiable benefits to mankind.

- To explore and understand the universe.

Moving toward the achievement of these goals requires the development and application of new technology to provide the capabilities needed for future operations in space. In turn, we must learn to utilize these new capabilities for the benefit of mankind and to explore the far reaches of space. Thus, NASA's planning toward its future program in space reflects these requirements.

To provide a focus for this program in pursuit of the Agency's space goals, several broad program objectives have been established. These program objectives are:

- To develop the technology and the space vehicle systems necessary to operate in space and explore space near the earth, on the moon, and throughout our solar system; and to utilize the unique capabilities of man in these vehicle systems to enhance space operations and exploration.

- To develop the space capabilities that contribute to management of the earth's resources and the human environment, and to facilitate the application of space systems to the needs of communication and navigation.

- To explore and understand the moon, the planets and space environment in our solar system, the sun and the cosmic environment, and the behavior of organisms in the environment of space.

In the pages that follow we discuss these goals and objectives in detail for each of NASA's program categories. Also, we bring out the values that are associated with the achievement of the goals and objectives. The technique used to highlight the values is to indicate future capabilities that are believed achievable with an adequate application of resources.

GOALS AND OBJECTIVES FOR AMERICA'S NEXT DECADES IN SPACE

TABLE OF CONTENTS PAGE

EARTH ORBIT [illegible]

The first decade of manned space flight demonstrated the capability for men to operate in space and began the development and exploitation of this capability through the program to land men on the moon. Building on the success of Project Mercury, the Gemini and Apollo programs were initiated to provide the space vehicle systems, facilities, and trained manpower for the steps leading to the successful manned lunar landings completed to date.

In the course of these programs we have developed and demonstrated the following capabilities:

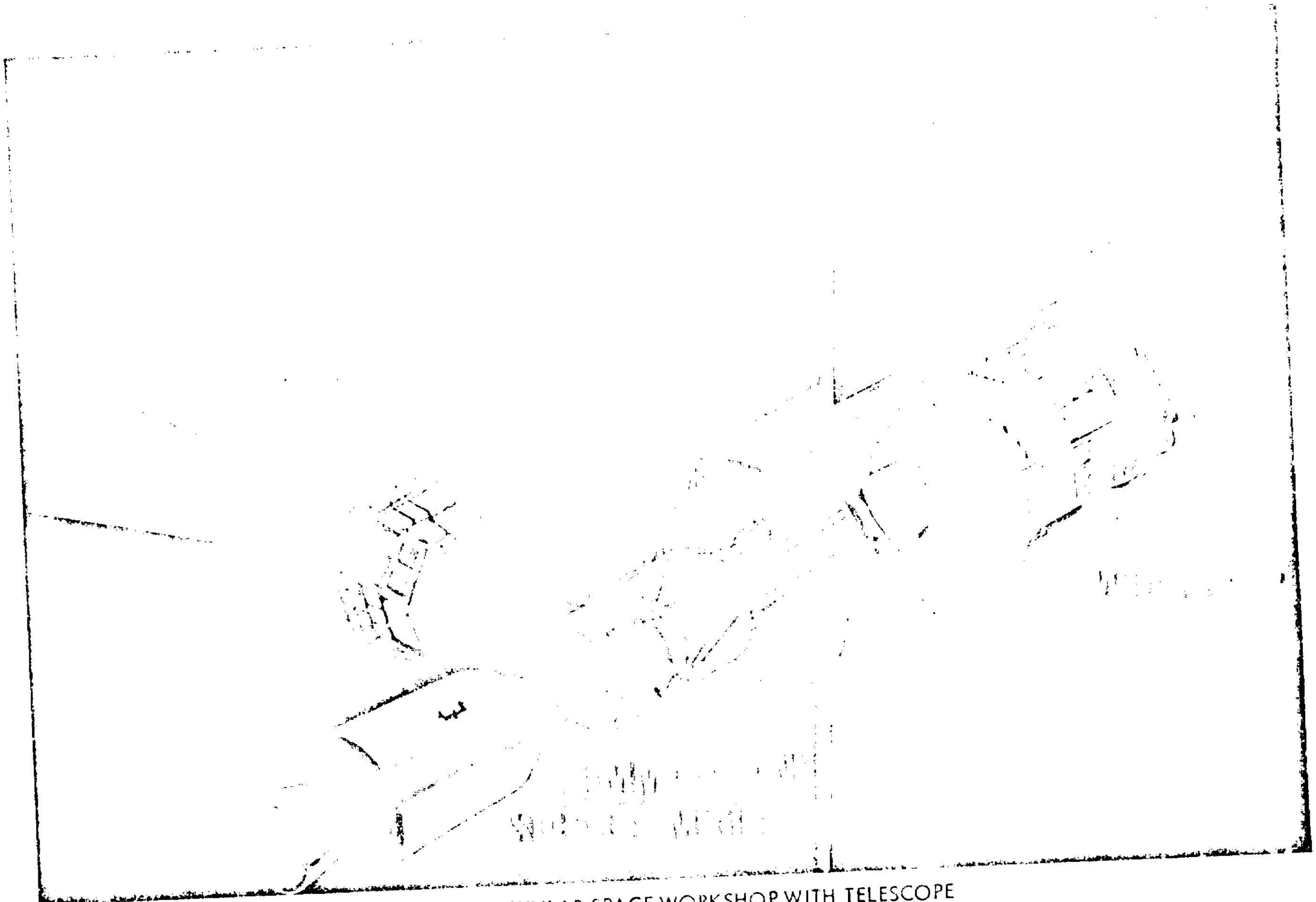
- A Saturn V system that can place 250,000 pounds in low earth orbit and send a 100,000 pound payload to the moon.
- Spacecraft systems that can support three men in space for periods of two weeks.
- Spacecraft systems that can place men on the moon and return them safely to earth with samples of the lunar surface.
- The ability of men to perform useful work in earth and lunar orbit and on the moon.

It is planned that the Apollo program will continue the manned lunar exploration activity and further exploit the significant scientific capability demonstrated by Apollo 11 and 12.

Project Skylab, which is scheduled to begin operational flights in 1972, will utilize Apollo hardware and systems to conduct extended manned operations in earth orbit. The basic structure of the upper stage of a Saturn V launch vehicle is being modified and outfitted as a space workshop, capable of sustaining three men in earth orbit for about 60 days. The program will include a series of manned visits to the workshop.

The prime objectives of Project Skylab are:

- To operate a broad spectrum of science and technology experiments that will be carried by the workshop, including the conduct of solar observations using a man-tended telescope.
- To obtain detailed data on the biomedical functioning of man for extended periods of time in the unique environment of space.
- To determine the habitation requirements for extended manned staytimes of man in space.
- To study the effectiveness and utility of man as an experimenter and space station operator.



PROJECT SKYLAB SPACE WORKSHOP WITH TELESCOPE

Goal

Although the Apollo Program and Project Skylab will substantially enhance our knowldege of manned space systems and permit the conduct of an extensive research program, more efficient and productive utilization of space must await projects and activities beyond Apollo and Project Skylab. Thus, our future program goal for earth orbital manned space flight has been identified as:

- The extension and utilization of the unique capabilities of manned space flight for the enhancement of our scientific and technological knowledge, for beneficial applications, and for the exploration of space.

Possible Future Capabilities

It is technically feasible for this nation to attain the following capabilities during the 1980's through aggressive pursuit of this goal:

- A large permanent general research, development, and operational base in earth orbit having the operational flexibility and capability necessary to support a broad spectrum of scientific, technological, and applications oriented activities.

- A number of small specialized stations at various orbital inclinations and altitudes capable of carrying out a wide range of scientific and applications activities.

- An operational transportation system capable of routinely moving men and materials to and from earth orbit at low cost in an environment comparable with that of modern transport aircraft.

- Completion of the necessary qualification of man, systems, equipment and procedures in support of very long duration manned flights such as extended lunar and planetary exploration missions.

The extent of the combined values that will accrue to the nation through the attainment of these capabilities cannot be projected with accuracy at this time. Their full value will be realized as experience develops our understanding of these capabilities and allows their beneficial application. However, among those things that application of these capabilities will permit and enhance are the following:

- The ability to carry out science, applications, and technology activities in space under living and working conditions similar to those found in ground-based facilities.

- Facilities in the space environment that could be used to study and develop new technologies, materials, and processes that cannot be developed on the earth.

- A research and development facility in space that other government agencies could use for general and specific purposes related to their own areas of responsibility in much the same way that present government-owned ground-based laboratories are utilized.

- A capability to conduct selected research, development, and eventually operational activities which require special orbit characteristics.

- A reduction in earth-to-orbit transportation costs sufficient to make the use of space economically accessible to a broad spectrum of users both for manned experiments and for launching special automated payloads.

- A transportation system with low levels of acceleration during launch and reentry that would permit the use of a broad spectrum of scientists, engineers, and technicians in space and not require the degree of specialized training and physical conditioning required for astronauts.

- The ability to service automated satellites, designed for manned attendance, in space or to transport them back to the ground.

- Multipurpose earth-to-orbit and orbit-to-orbit transportation vehicles that could have additional utility for defense purposes.

- An ability for foreign nationals to participate in orbital activities with United States scientists and engineers, thus forming the basis for broader international cooperation.

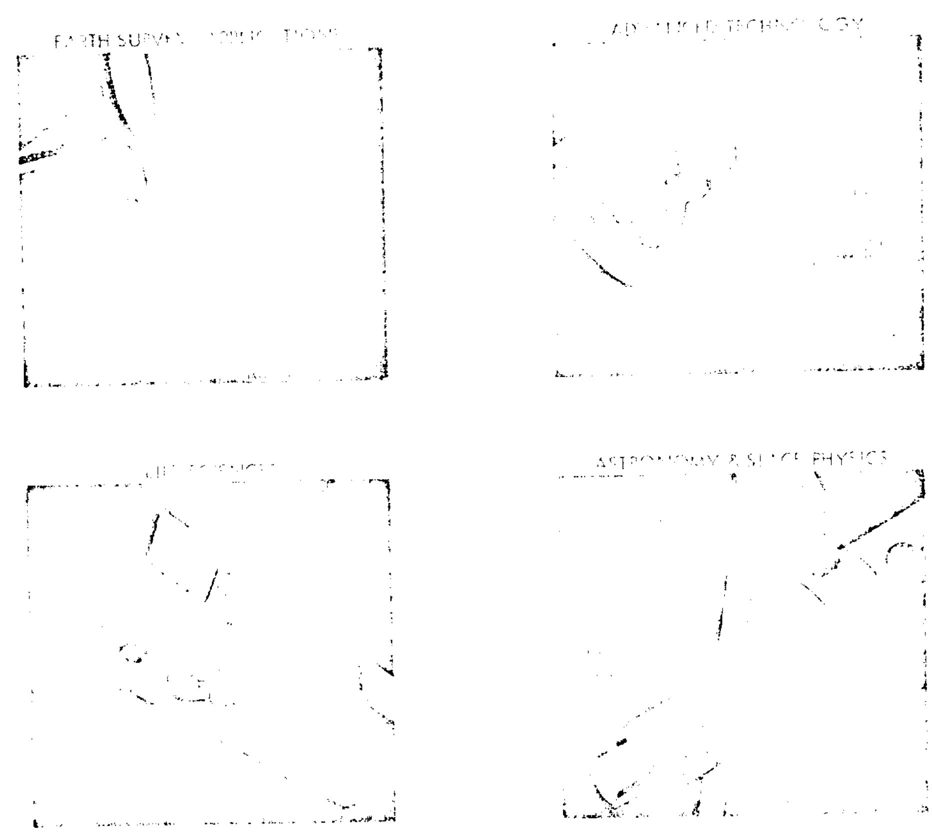
- An ability to apply systems and technology developed for earth orbital operations to manned exploration of the moon and Mars.

- The ability to develop in earth orbit, prior to the time for commitment, technology, equipment, and operating procedures applicable to manned exploration of Mars. This provides information that will permit a manned planetary mission decision to be made with a high degree of confidence in estimates of technical feasibility, resource requirements, and development schedules.

OBJECTIVES

In order to achieve the capabilities necessary to carry out a comprehensive space program during the next two decades, significant extensions to our knowledge and technology must be made. These will include significant increases in our understanding of man's capabilities and requirements in the space environment as well as a further development of man's capability to carry out scientific, technological, and applications programs that are planned for earth orbital operations. To support the goal of earth orbital manned space flight and to attain the possible future capabilities, several broad objectives have been identified. The first of these is:

1 - Define, select, develop, and conduct scientific, technological, and applied experiments that are advantageously associated with a manned system.



UTILIZATION OF MAN IN EARTH ORBIT FOR SCIENTIFIC, TECHNOLOGICAL, AND APPLICATIONS PROGRAMS

This objective is directed at the identification and implementation of activities that [illegible] the best use of a space station. Such effort will involve the conduct of varied types [illegible] ments in order to learn which are enhanced the most by the presence of the crew. [illegible] involve experimentation with new technological or developmental uses of space sta[illegible] activities will be conducted with a view toward developing the full utility of the [illegible] ronmental capability space stations offer as well as developing technologies and cap[illegible] which can be used in lunar and planetary exploration. These activities are characte[illegible] the following specific objectives:

- Obtain biomedical and behavioral data on men in space over extended periods of time (from six months to up to two years in duration) and at various levels of artificial gravity.

- Conduct tests and studies pertinent to the development of design criteria for habitation, life support and protective equipment for men in long-duration space operations.

- Establish a capability to conduct rapid testing and assessment of a wide variety of earth-oriented and other earth survey-systems sensors in the orbital environment.

- Establish the capability to support research in space on materials and processes such as the production of lightweight high strength metals by levitation fo[illegible] and the production of large crystals for application to electronics.

- Identify requirements for, and develop equipment and procedures to assure the effectiveness of man in, the pursuit of science experiments, applications tasks, and vehicle operations such as telescope manipulations, laboratory techniques, extravehicular activities, rescue, docking, and cargo handling.

- Identify requirements for, and develop operational concepts and techniques to conduct, activities and experiments in support of major scientific and applied disciplines, such as astronomy, bioscience, physical science, and space manufacturing.

Closely allied to the first broad objective is the need to capitalize on the scientific and engineering results and the operating experience obtained with the space station in a way that provides both direct and indirect benefits. This need leads to the following broad objective:

2 - Identify, evaluate, and exploit the economic, scientific, technical, social, and geopolitical implications of a long-duration manned space facility.

Early space station operations in pursuit of the above specific objectives are prerequisites to achieving the second broad objective. The following specific objectives also contribute to the identification of the activities through which the space station can be utilized and exploited for maximum benefit:

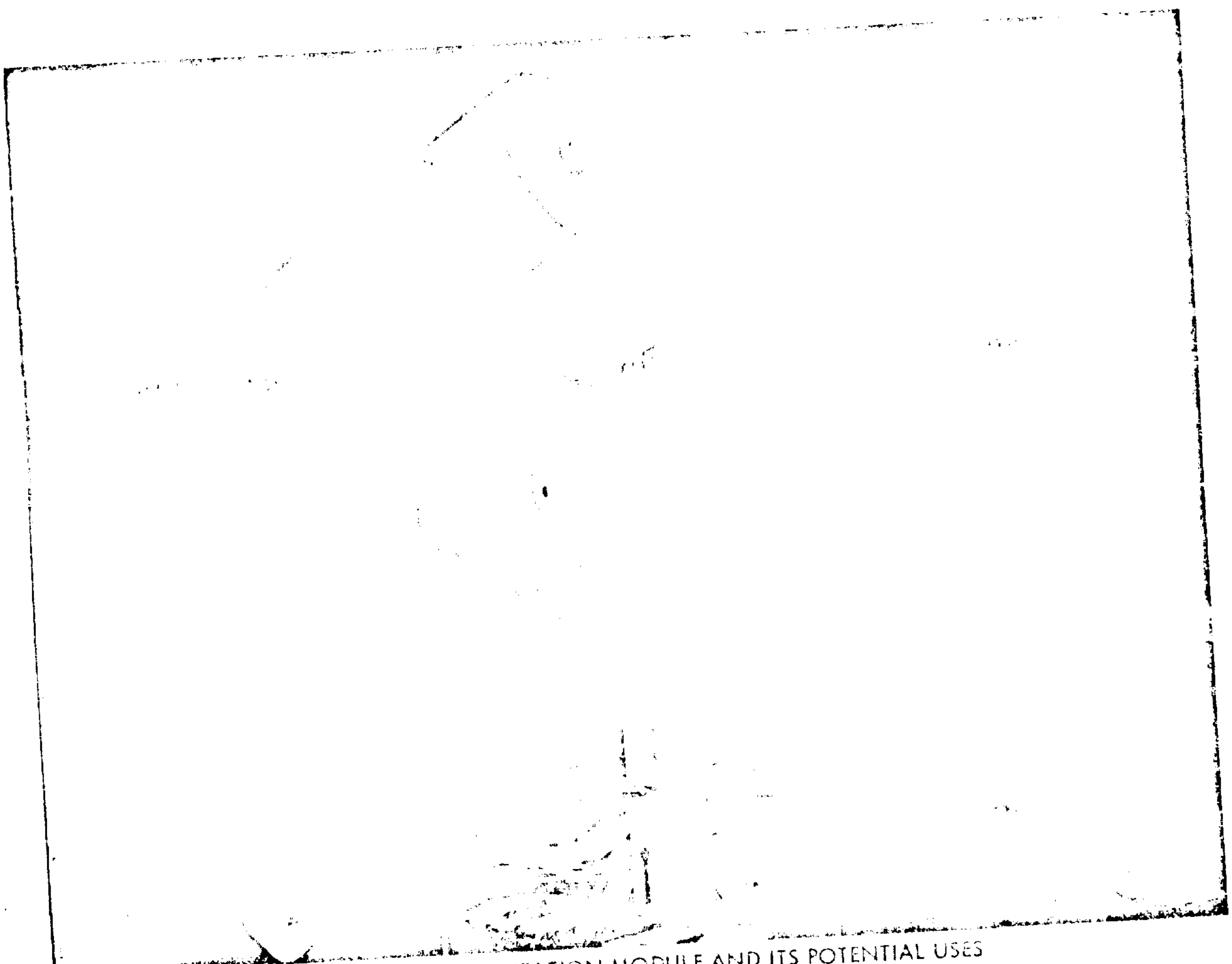
- Identify and develop, with the help of representatives of industry, the universities, and other government agencies, technical and operational concepts that have been demonstrated to require the unique environment of space and to benefit from or require the participation of man.

- Identify requirements for, and concepts of, laboratories, observatories, and other user facilities and the associated operational techniques and procedures necessary for implementation of programs.

- Establish a framework for international participation.

In conjunction with the first two broad objectives, it will be necessary to further develop our capabilities to carry out manned earth orbital operations. This extension of our capabilities will make it possible to realize the benefits of long-term earth orbital flight. The next objective supports this requirement:

3 - Develop and demonstrate practical concepts for establishing, operating, and maintaining long-duration space stations, involving significant increases in useful life.



CONCEPT OF SPACE STATION MODULE AND ITS POTENTIAL USES

Achievement of this objective implies the design, development, and operation of one or several space stations on a permanent basis. This will require the extension of current capabilities and the development of new concepts in a number of areas. Some of the most important and evident concepts are: Extend component and subsystem lifetimes to several years; observe and define the reactions and physical limitations of the crew for extended periods of time; define, develop, and demonstrate the environment and support systems to which man is most compatible in space; define and implement the ground operations required to continuously support a space station; develop and put into use routine and emergency operating procedures for a space station; and establish an understanding of the types of tasks that the crew can best perform in operating the space station and in conducting experiments.

Based on this broad objective, the following specific objectives have been established:

- Develop and operate space station modules that can accommodate up to twelve men; that can support laboratories and observatories for the pursuit of science, applications and technology goals; and that will incorporate the capability to support space operations such as providing services to satellites or remotely operated modules.

- Define and develop the techniques and equipment for clustering space station modules to establish a large general purpose research and development facility.

- Develop and gain operating experience related to the resupply and maintenance of multimanned space stations, including the resupply of expendables as well as equipment and experiment payloads from earth-to-orbit and orbit-to-orbit.

- Evaluate man's capability to survive in space for long periods of time under a variety of artificial gravity conditions.

- Develop and demonstrate, under operational conditions, suitable modes of manned operation outside and within a space station for routine and emergency activities.

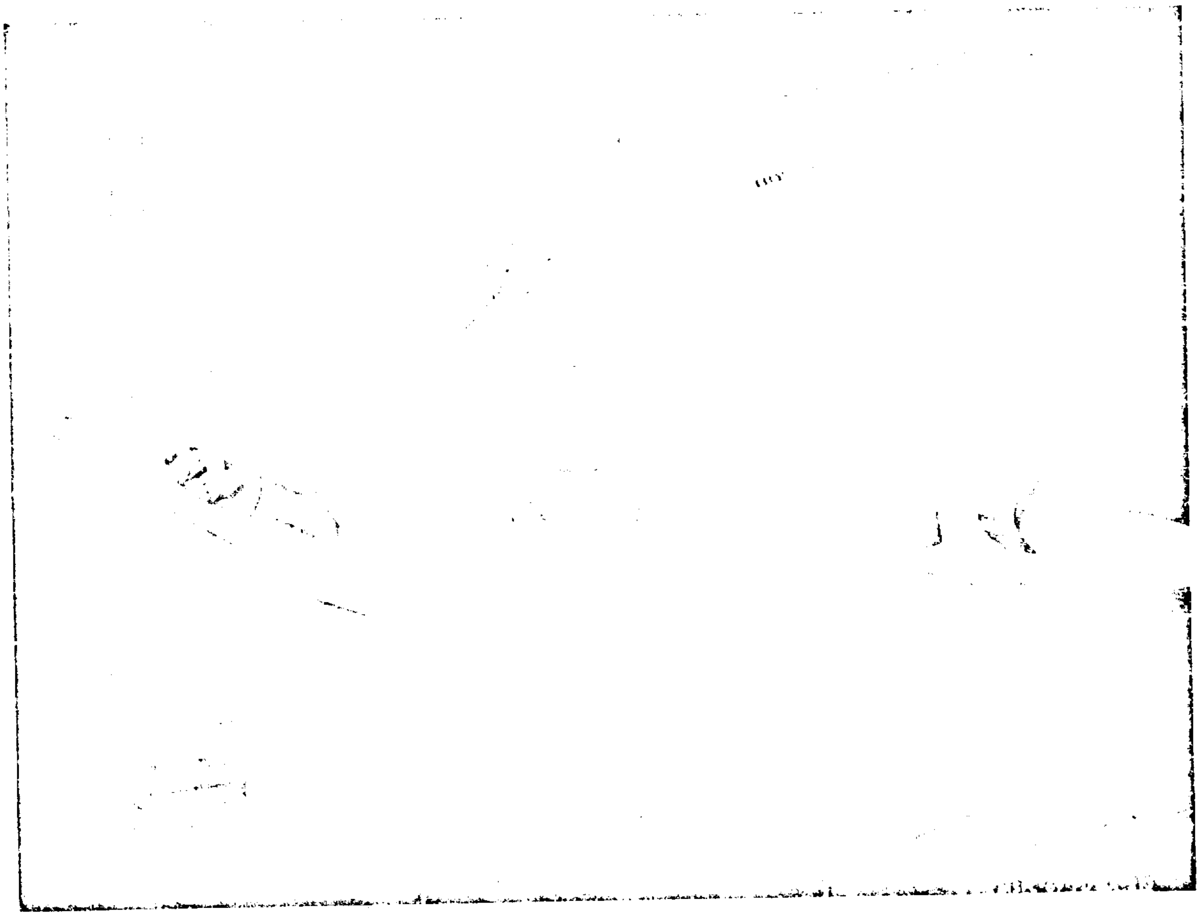
- Identify needs and develop means to capitalize on man's abilities and his participation as an experimenter and operator in space.

The ultimate extent to which manned systems will become important tools for mankind will be dependent upon their costs. Therefore, a fourth important broad objective of the program is:

4 - Improve the effectiveness and lower the costs of manned space flight systems and operations.

This objective relates to the space station and to the transportation system that will carry men and material between earth and the space station and between the station and systems it supports in other orbits. It will be important that the space station be designed to operate with a minimum of logistics requirements. This implies a great deal of self-sufficiency in terms of long-life components, on-orbit maintenance and repair in the event of failures, and flexibility to adapt readily to changes in the experiments or on-board operations.

In contrast to current systems, the transportation system should embody airplane-like characteristics to the maximum extent possible in terms of reuseability, availability for rapid turn-around, and level of ground support.



CONCEPT OF A REUSABLE EARTH-TO-ORBIT LOGISTIC SYSTEM AND ITS PLANNED USES

The specific objectives that will lead to these space station and transportation system capabilities are:

- Develop and operate a low-cost earth-to-space and earth-return transportation system which will be designed to operate with minimum ground support, allow recovery and reuse of the major subsystems, and require minimum refurbishment between flights.

- Develop long-duration space systems which utilize high reliability components to minimize resupply and repair requirements, and which also take advantage of modular techniques to allow use of on-orbit maintenance and repair in case of failure.

- Define and develop a modular space station concept which offers flexibility to adapt to changing mission requirements and payloads, and which would also be adaptable to extended lunar exploration and manned missions to Mars.

Before a program of extended manned lunar exploration is initiated or a national commitment is made to proceed with a manned planetary flight program, it will be desirable to conduct tests of critical components and subsystems in an environment and for durations simulating extended operation on the moon and flights to Mars. During the development phase of such programs, there will be a variety of demonstration tests that will be desirable in a space environment. It will also be necessary to conduct tests on man to assure his well being for the duration and in the environment of a planetary mission. Such tests will also prove useful for developing equipment and procedures applicable to extended operation on the moon. Thus, the following broad objective has been developed:

5 - Use earth orbital manned flights for test and development of equipment and operational techniques applicable to manned lunar and planetary exploration.

The manned space station is viewed as a laboratory facility in space where manned lunar and planetary program tests can be conducted. The following specific objectives have been defined for these activities.

- Obtain biomedical, behavioral, and performance data on man and develop the techniques and protocol pertinent to the maintenance of his well being for periods of flight extending to those required for missions to Mars.

- Fly an operating space station module continuously for durations typical of Mars flight times to obtain data pertinent to the establishment of design criteria for manned systems that are required to perform over these time periods and to verify proposed operational techniques for the conduct of such missions.

- Design, develop, and flight test critical long-lead items and procedures required for extended lunar operations and for expeditions to Mars.

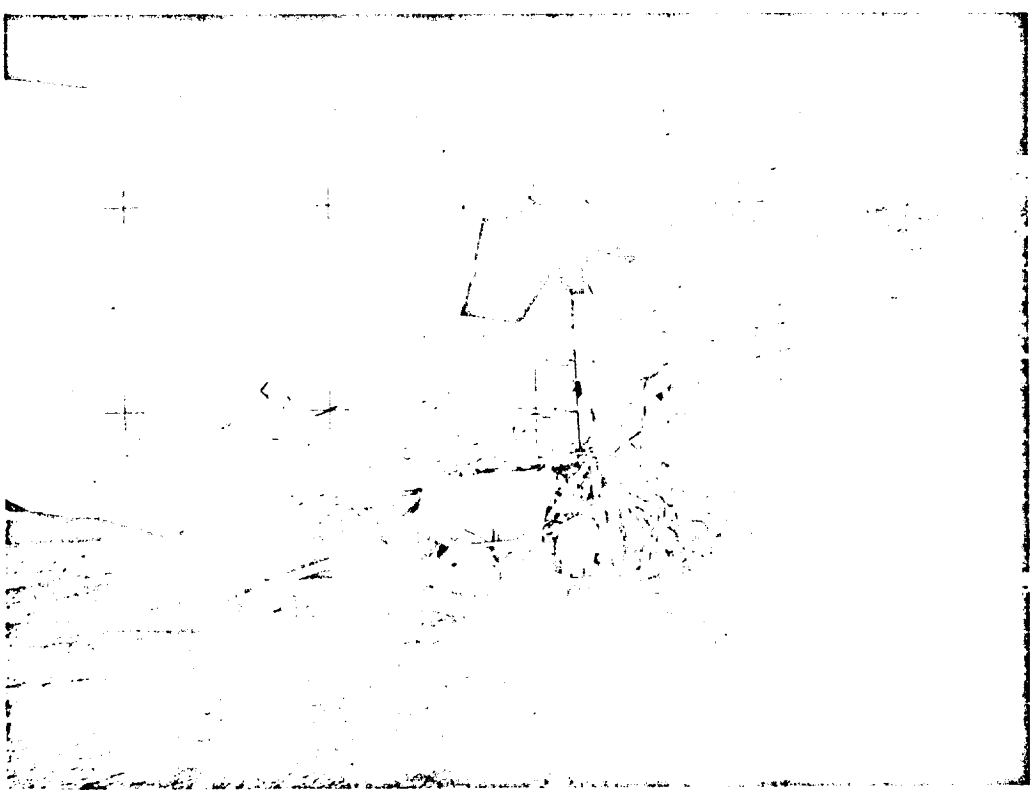
LUNAR EXPLORATION

The past ten years have greatly expanded our knowledge of the moon as our Nation prepared for and accomplished the manned lunar landing goal. Unmanned spacecraft were the first flight vehicles used for lunar exploration. They provided both scientific and engineering information of importance to the manned Apollo landings. The scientific data assisted in the planning of the science activities to be conducted by the astronauts. The engineering data, such as soil bearing strength, extent of dust cover, surface photographs, and guidance and navigation parameters for orbit and landing confirmed the adequacy of the LM design for landing on the moon and aided in planning the flight profile characteristics from orbit to touchdown.

Basic problems being addressed in the exploration of the moon fall chiefly into three categories:

- Composition and structure of the surface of the moon and processes modifying the surface.
- Structure and processes of the lunar interior.
- History or evolutionary sequence of events by which the moon has arrived at its present configuration.

As a result of Ranger and Lunar Orbiter photography, we felt certain that volcanic activity had occurred on the moon and might still be taking place. Detailed photos of sinuous rilles, with meandering patterns quite like terrestrial rivers, suggested flowing water and past



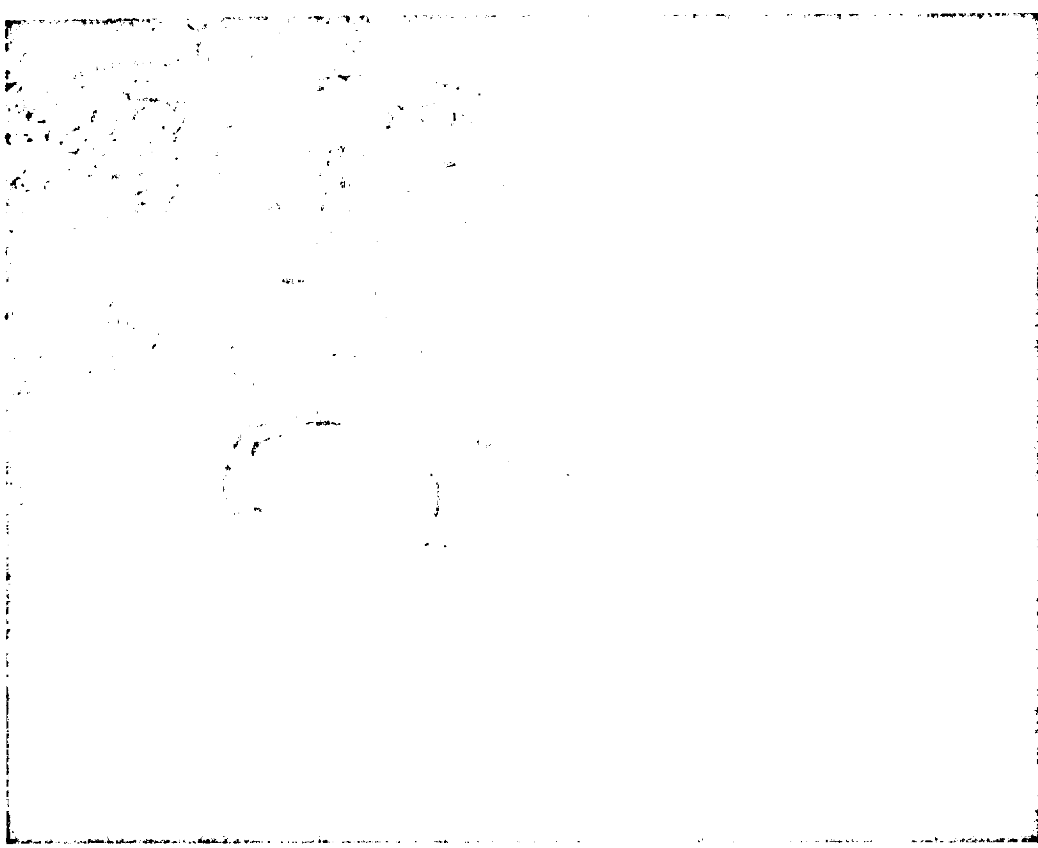
SURVEYOR III VISITED BY APOLLO 12

atmospheres. Elemental analysis measured by the Surveyor spacecraft showed a similarity to terrestrial volcanic rock -- basalt. The samples Apollo astronauts brought back are similar in many respects to basalt found on the floor of our ocean basins, yet they are compositionally distinct from earth rocks. The "melting pot" in which they formed was very hot -- perhaps 2000°F -- comparable to volcanic chambers of the earth. However, little or no water was present when the lunar rocks solidified.

Chips of an entirely different rock -- not basalt -- have also been found in the returned samples and are believed to have been thrown into the area by meteor impacts in the highlands. Confirmation will have to await a highland landing.

Lunar Orbiter's discovery of local mass-concentrations, "mascons", which warp the lunar gravity field near large circular basins, indicates that the lunar interior is cooler and more rigid than that of the earth. This conclusion is supported by measurements made by Anchored IMP (Explorer XXXV) in lunar orbit; its observations suggest lower electrical conductivity in the interior and lower temperature in the outer portions of the moon.

In order to better understand the nature of the moon's internal structure, seismic data is of prime importance. Seismometers emplaced by Apollo 11 and 12 have recorded a number of natural events which may be meteorite impacts or volcanic activity -- they do not appear to be sudden movement along a fault trace. The most puzzling data occurred when we deliberately impacted the Lunar Module after the astronauts were through with it. The resulting signal lasted for almost an hour -- on earth it would have been over in minutes. Seismic velocities suggest that there is extensive shattering near the surface, beneath which an efficient wave-guide exists, quite different from the crust of the earth.

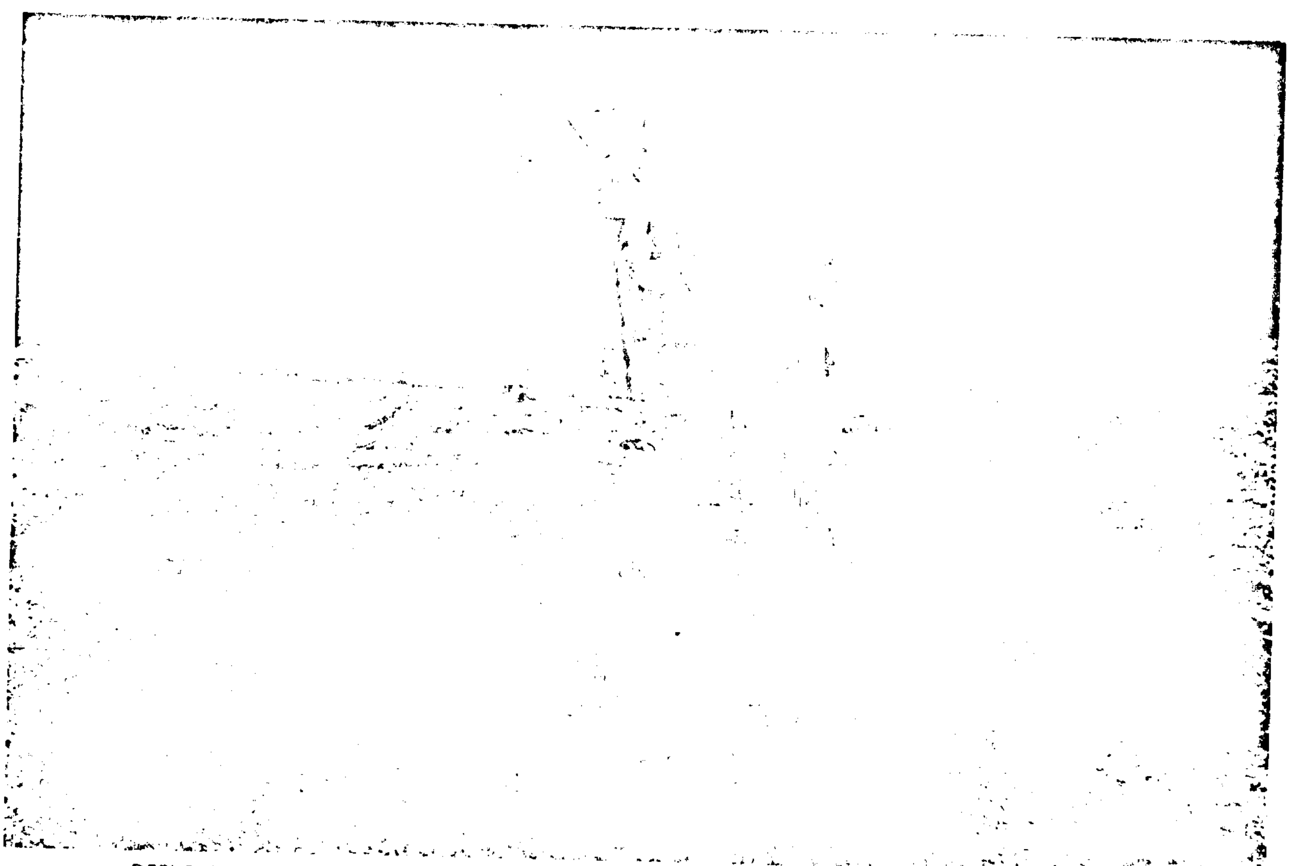


TRIESNECKER RILLES ADJACENT TO TRIESNECKER CRATER

Even more surprising is Apollo 12's discovery of a weak magnetic field, 5 to 10 times greater than was expected from Anchored IMP and Soviet data. Residual magnetism has also been found in some of the lunar specimens. The moon may well have had a significant magnetic field long ago, when it was much closer to the earth. Many theories relate the earth's strong field to its liquid core, so the possibility is raised that the moon may have had a molten interior at one time in the past.

Telescopic studies of the lunar surface in the visible, infrared, ultraviolet, and microwave portions of the electromagnetic spectrum suggest that the moon is chemically and mineralogically heterogeneous. The rocks from Apollo 12 are a billion years younger than those from Tranquility Base (Apollo 11) and differ chemically. Thus, the moon experienced at least two periods of volcanic activity which led to the emplacement of these two different age rocks.

The rocks from Apollo 11 and 12 are from the dark "mare" or seas, which are among the youngest features on the lunar surface. These basalt flows fill enormous basins carved out of the older highland surface. Samples from the Ocean of Storms (Apollo 12) are about 2.5 billion years old; rocks from Tranquility Base are more than 3.5 billion years old, as old as the oldest rocks found on earth. The reason age is so significant is that we suspect our earth and moon, along with the rest of the solar system, formed about 4.6 billion years ago. We know nothing of what happened on earth in its early history, because erosion by water and the atmosphere has completely erased this record. We now know that changes occur far more slowly on the moon, preserving clues to the earth's origin and early history. Some of the returned material has been shown to be a billion years older than any ever found on earth. It dates back almost to the time we believe that the planets were actually formed -- making the moon a "rosetta stone".



DEPLOYMENT OF LUNAR SURFACE EXPERIMENTS ADJACENT TO APOLLO 11 LUNAR MODULE

These rocks have lain on or near the surface for varying periods up to 550 million years, recording variations in the sun's activity. From the lunar samples it may be possible, through correlation with past ice ages and tropical periods, to understand the influence of solar activity on the earth's climate.

The current plan is to continue manned lunar exploration, utilizing the Apollo procured launch vehicles and spacecraft that remain on hand, for landings at craters, in the highlands, and near river-like rilles to study these different features, and to determine the chronology of major events leading to their formation.

Goal

Although these Apollo type lunar missions will substantially increase our knowledge about the moon, we will still have only scratched the surface. There will remain much of importance to learn about the moon, both in terms of scientific information and of how the moon and our capability to operate on it can be usefully applied. Thus, we have established the following goal for the Lunar Exploration Program:

- To explore and utilize the moon for the benefit of mankind.

Possible Future Achievements

If this goal is actively pursued, the following levels of achievement could be reached by the mid-1980's:

- To have explored all major regions of the moon.
- To have established a permanent lunar base.

Exploration in the context of the planned program would require manned or unmanned visits to sites of prime scientific interest representative of geological features, or formations believed to have resulted from meteor impact, volcanic action, or mountain building. Some of these sites will be on the moon's far side. In addition to local investigations, manned and/or unmanned traverses are needed to understand the changes which are associated with the transition from one type of major surface feature to another type. An example of this is the contact between the relatively flat "seas" and the adjoining mountain regions. In general, it will be necessary to examine the form and subsurface nature of examples of the "seas", mountains, craters, and other lunar features in order to learn how they relate to each other and the processes which caused their formation.

Values resulting from accomplishing this projected exploration will include identification of the moon's origin, age, and history. In turn, this knowledge will extend our understanding of the evolution of the solar system and lead to answers concerning the evolution of the earth and man. Study of the moon's seismic activity, volcanism, faulting, and mascons will yield information applicable to the solution of current unresolved questions in our understanding of the earth.

The establishment of a lunar base would provide a center for continued exploration activity and furnish laboratory space for specialized science, applications, and technological research that requires or utilizes the moon's unique environment or its isolation from the earth. This would be an important milestone in the effort to utilize the moon for the benefit of mankind.

In looking forward to man's possible future in space exploration, the base could be used to develop man's capabilities to operate for extended periods of time on another planet in preparation for manned planetary exploration. The availability of laboratory facilities would also furnish opportunities for cooperative participation by other nations.

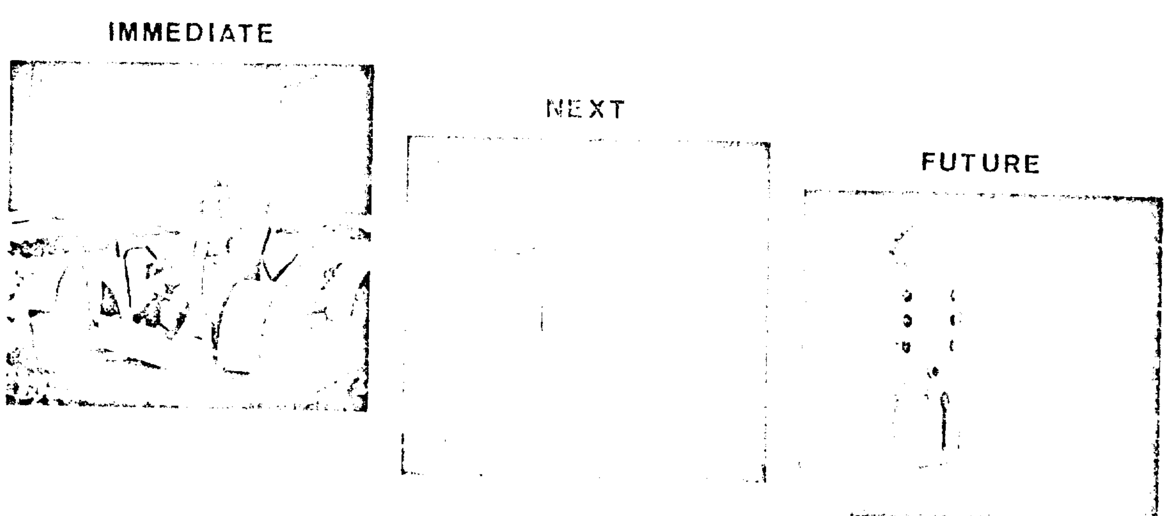
Objectives

In order to achieve the identified goal, three broad objectives have been developed. The first is:

I - To understand the moon in terms of its origin and evolution; to search its surface for evidence related to the origin of life; and to apply new data on the differences and similarities between the earth and moon to the reasonable prediction of dynamic processes that shape our planet.

Reaching this objective implies a broad spectrum of lunar-wide scientific investigations. The purpose of these investigations will be to study problems such as the moon's current external and internal structure. Major surface features and their origin must be investigated, including the variation of chemical composition from feature to feature. In addition, the surface and near space environment of the moon requires study both for identification and to understand their relationship to lunar history. There would be complementary investigations aimed at understanding the history of the moon and its environment not only as an entity, but as a part of the earth-moon and solar systems. A major analytical effort will be undertaken to integrate the information collected into theories and/or conclusions related to the moon, and the earth-moon and solar systems. As part of the anlytical effort, comparisons will be made between the moon and earth in an attempt to better understand the history and future of the earth and its environment.

Concurrent with the above effort there will be a continuing search for organic compounds, fossil life forms, and micro-organisms. The results of this search, interpreted in context with data on the history of the moon will then be tested against current theories on the mechanisms related to the origin of life.



FUTURE LUNAR SCIENTIFIC INVESTIGATIONS

The broad scope of activity and types of information associated with the fo[illegible] effort have resulted in the establishment of the following supporting specific objectives

- Investigate the major classes of lunar surface features (mare and h[illegible]), surface processes (impact, volcanic, and mountain-building), and [illegible]ional problems (mare-highland relation, major basins and valleys, volc[illegible]c provinces, major faults, and sinuous rilles). Define their form, r[illegible]ional setting and subsurface nature by landings at key sites and by extended traverses over the surface.

- Completely characterize the samples collected at each site and during each traverse by detailed analysis on earth, including rock identification, chemical composition, and age dating.

- Determine the gross structure, processes, and energy budget of the lunar interior by measuring seismic activity, heat flow, and disturbance in the moon's axis of rotation with a widely spread (approximately 1000 Km. apart) network of long-lived surface instrumentation.

- Survey and measure the lunar surface from orbit about the moon with metric and high-resolution photography and remote sensing, tying together local studies and long-range traverses into a regional framework. Provide detailed information for science planning of surface missions, and lunar-wide control of surface position and profile.

- Investigate the near-moon environment and the interaction of the moon with the solar wind; map the gravitational field and any internally produced magnetic fields; and detect atmospheric components resulting from the neutralized solar wind and micrometeorite flux impact-effects by long-term monitoring with lunar orbiting satellites.

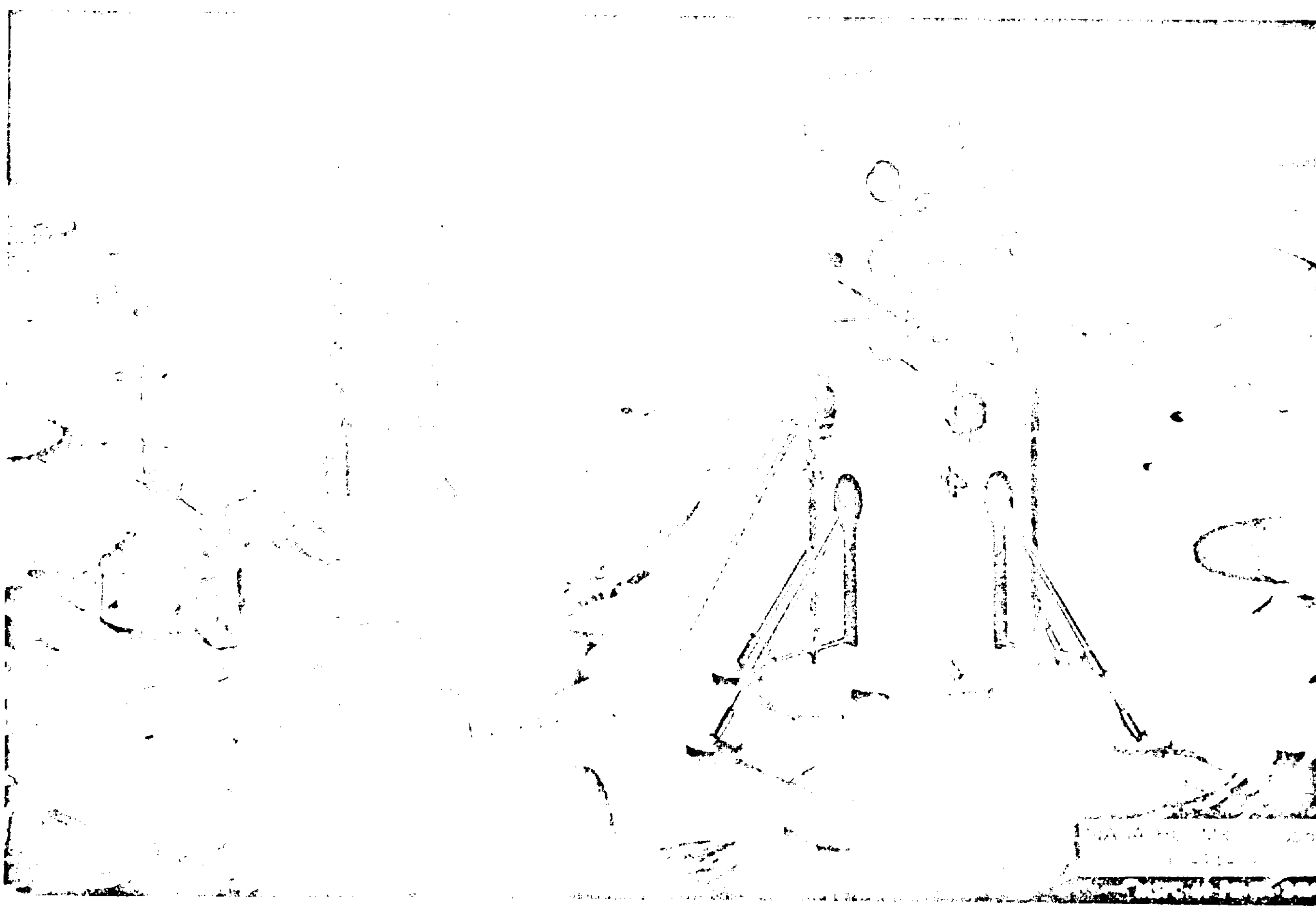
- Return uncontaminated samples to earth for analysis of biologically related organics (such as prebiotic material, fossil life forms and micro-organisms) and determine their origin; conduct in situ analyses for biological material on the moon, particularly at sites of special interest, and relate these data to a comprehensive theory on the origin of life by comparison with the earth and the planets.

- Determine how geologic processes work on the moon in the absence of an atmosphere, fully exposed to the solar wind and with one-sixth the force of gravity, in order to gain a much deeper understanding of the dynamic processes that shape our terrestrial environment.

In order to fully satisfy our aims with respect to exploration and utilization of the moon, it will be necessary to develop new technologies and capabilities. Accordingly, the second broad objective is:

2 - Develop the technology essential for a continued lunar program which will permit the effective utilization of the moon.

The activity which will support this objective will be directed toward a number of important developments and will utilize to the maximum extent possible those capabilities and systems developed for earth orbital manned space flight. Permanent shelters with which to establish a surface base and equipment to carry out lunar surface operations over extended distances will be required. The ability to communicate from the far side of the moon and from point-to-point on the near side will be necessary. There must be a reduction in the cost of earth-moon transportation. Methods and equipment to minimize astronaut hazards must be developed. A reduction must be made in the dependence on earth provided consumables for life support and power. If it becomes evident that the natural resources or the environment of the moon are worth exploiting, the capability to do this must be developed. In a like manner, if the use of the moon for such things as a weather-watch or communications station is found to be worthwhile, the applicable technologies must be developed. Also, the manner in which the moon can be used effectively as a site to develop procedures and demonstrate systems for use in manned planetary exploration should be determined and its use for this purpose developed. Through this type of effort, man will be provided with the capability to conduct lunar operations more efficiently and to benefit from the results of his discoveries.



CONCEPT OF AN EARLY LUNAR SURFACE BASE

The activity needed to achieve this objective is essentially technological in nature. Thus, the following supporting specific objectives have been established:

- Provide the capability to conduct long-range operations across the lunar surface with reliable surface vehicles and equipment during both day and night operations.

- Develop the equipment and supporting systems such as shelters, power, communication, and data processing required to establish a surface base and to support lunar operations.

- Provide for long-term independence from earth consumables by reliance on lunar resources and closed ecological systems.

- Minimize problems and risks of long-term survival including provisions for reliable rescue or escape.

- Utilize technology advances to reduce the cost of earth-moon transportation.

- Where beneficial, provide the ability to implement manufacturing processes on the moon.

- Exploit the advantages of the moon's vantage point by providing suitable installations for supporting earth applications and planetary missions.

- Utilize the moon for developing procedures and testing systems that will be used for manned planetary exploration.

The final broad objective emphasizes the importance of a lunar base. In a sense it parallels man's efforts to expand his domain here on earth by establishing permanent and semi-permanent bases in the Antarctic where long-term scientific investigations have been taking place. Just as it was necessary to make those bases semi-independent, it is evident that an even greater degree of independence will be needed for similar establishments on the moon. In this context the third broad objective is:

3 - To extend man's domain to include the moon.

In order to reach this objective, it will first be necessary to determine whether there are lunar materials which can be used to reduce man's dependence on earth to an acceptable level. If such materials are identified in sufficient concentration at an acceptable site, it will be necessary to develop methods by which they can be utilized. Techniques for extracting basic elements such as oxygen and hydrogen, from the lunar raw materials will be required. Methods and equipment for gathering or mining the raw materials must be devised. The problem of how materials for construction can be obtained and used must be solved.

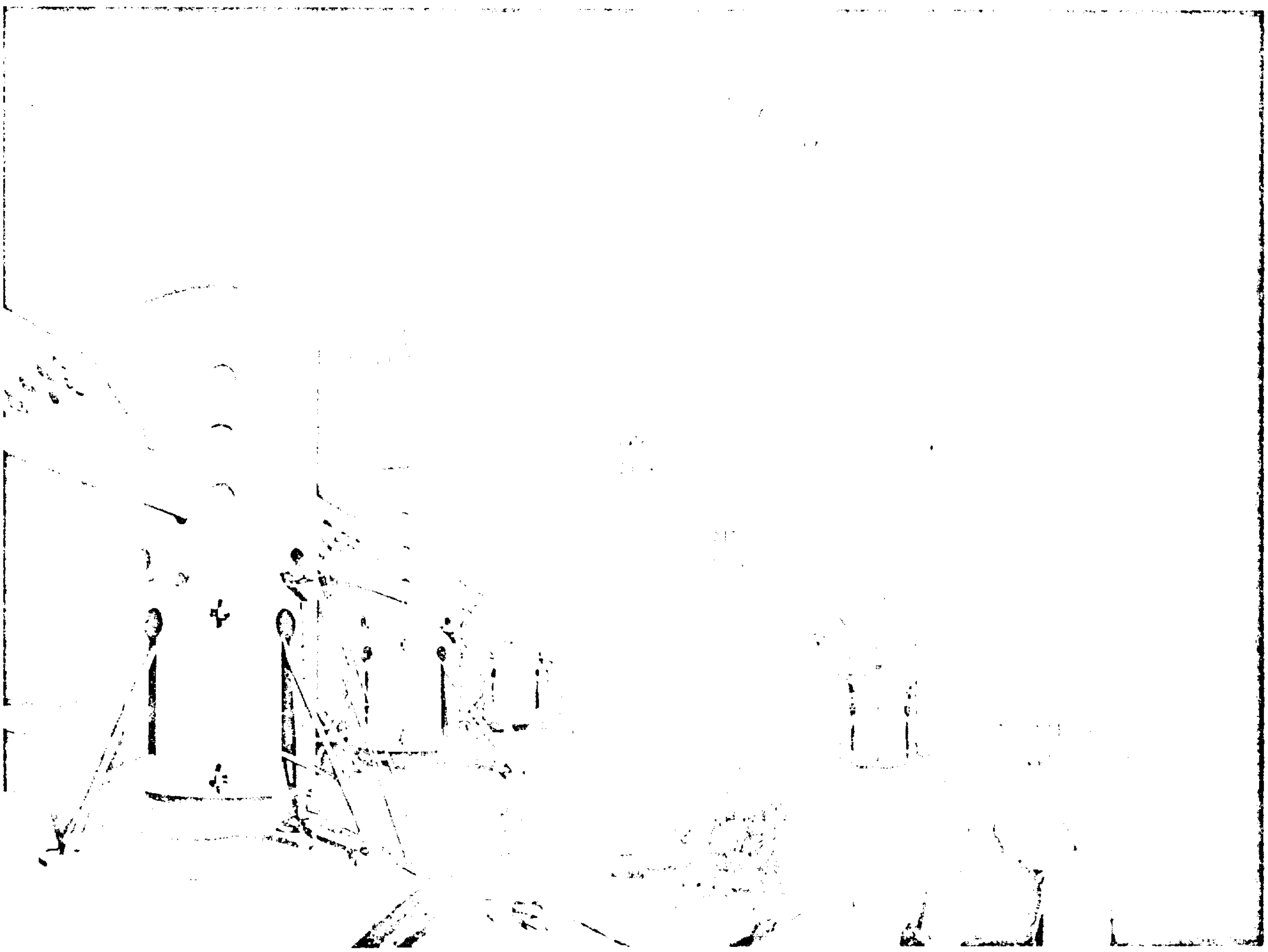
Extending man's domain also requires that man be able to reside and work on the moon for extended periods of time in the environment created for him. It also entails the conduct of activity that is useful to man.

With these requirements in mind, the following supporting specific objectives have been identified:

- Investigate and locate lunar resources; establish their utility for life support, power, propellants, and construction; and determine their value for use on earth.

- Conduct significant long-term scientific and engineering operations leading to the use of the moon as a platform in space, including astronomical and biological experiments especially suited to the lunar environment.

- Determine whether man can live for extended periods on the moon and function as a planetary explorer and space engineer.



LUNAR BASE CONCEPT FOR LONG-TERM SCIENTIFIC AND ENGINEERING OPERATIONS

SPACE MEDICINE

The Space Medicine Program is designed to determine man's capabilities and limitations in the space environment and to develop the technology pertinent to support, protective, and other systems which will permit him to function and perform effectively. This program has been pursued through ground-based and flight research programs on man, animals, and other biological systems; studies of man as an operator and controller; and research and development programs related to life support, protective and other systems required to support man. Major program emphasis has been directed to the development of information which could be translated into design data and criteria for future manned space systems.

With the flight of Apollo 12, 26 men have participated in 22 United States manned space flights and have gained approximately 7,400 man hours of experience in space operations. As a result of these flights, we know that highly trained men can withstand the rigors of functioning in a weightless state for as long as two weeks.

However, this flight experience coupled with its limited ground-based supporting research does not adequately establish the scientific basic required to qualify man and his supporting equipment for future extended duration space missions. Indeed, the nature of man's proper role in future extended duration space flight is dependent upon critical information yet to be obtained. This information must be based on a sound foundation of biomedical and engineering data to provide a background for meaningful design and development decisions for the next generation of manned spacecraft systems.

This technology base can only be achieved if multi-disciplinary environmental medical laboratories and universities develop closer ties with supporting industry. The development of Project Skylab biomedical flight experiments and the ensuing results from these experiments, will provide a focus for the participation of medical laboratories in the increased ground program and a better definition of problems and their priorities for prolonged weightless space flight.

Goal

In context with the current status and the future needs of this program, the goal established for the Space Medicine Program is:

- To develop an understanding of man and his supporting equipment which will allow the establishment of design criteria for optimal use of man in space operations.

Possible Future Capabilities

A continuing and comprehensive ground-based and flight research Space Medicine Program could, in the next ten to fifteen years, place the Nation in a position to utilize the unique capabilities of man for extended space operations in earth orbit, on the lunar surface, and to nearby planets.

MAJOR EXPERIMENTS

- EXTRAVEHICULAR ACTIVITY
- SPACE SUITS
- ARTIFICIAL G
- LIFE SUPPORT
- HUMAN RESEARCH
- ANIMAL RESEARCH

SPACE MEDICINE RESEARCH IN EARTH ORBIT WILL DETERMINE MAN'S PHYSICAL CAPABILITIES AND REACTIONS

The accomplishments made as we progress toward attainment of our goal will yield new and increased capabilities for the Nation. These capabilities, which we could realize in the next ten to fifteen years, are described in the following paragraphs for the biomedical, man-systems integration, and life support areas of the Space Medicine Program:

Biomedical - Identified, as well as anticipated space-related problems of the various body systems should have been solved or at least well enough understood to be reasonably controlled. For example, basic problems of the cardiovascular system, such as reduction of blood volume, redistribution of body fluids, reduction of red blood cell mass, will have been resolved along with questions associated with respiratory gas requirements and physiological mechanisms. Calcium depletion associated with weightless flight will be better understood and controllable. Permissible levels of radiation exposure will be known. Through the delineation of pertinent physiological parameters and their measurement by innovative and non-invasive bioinstrumentation, prediction of physiological status and control of stress will be possible.

Man-Systems Integration - Man will be able to perform useful work efficiently and live comfortably in space. It will be possible to select the best qualified men and train them for particular missions in space. Small group dynamic characteristics and related habitability requirements will be known. Maintenance tools, techniques, and equipment will be available for functions inside and outside spacecraft and other space facilities.

Life Support and Protective Systems - It should be possible to provide nearly totally closed ecological systems for long duration space missions through the regeneration of waste materials into useful products. Efficient regeneration and reclamation processes will provide potable water and life-sustaining oxygen free of carbon-dioxide and other contaminants, and could provide materials useful for foodstuffs. Space suits and portable life support systems will be available as integral units without undue restriction to work or comfort. Within two decades regeneration of some food from metabolic wastes by physico-chemical means should be possible, and progress will have been made in the area of bioregenerative systems.

There are a number of benefits that will accrue to the Nation through the achievement of the capabilities just discussed. However, it should be realized that the full value of this activity cannot be envisioned at this time. Nevertheless, there are a number of benefits that can be foreseen at this time in space medicine, in general medicine, and public health.

Among these benefits will be the expansion of multidisciplinary systems analysis techniques required for a fuller understanding of man and his unique application in space activity which will be of direct value to man on earth in medical research and practice. Associated new biological sensor and bioinstrumentation techniques for multiple simultaneous measurements, and for measurements of small changes over long periods of time, will allow substantial increases in our general understanding of biological systems, especially man, and will provide new methods of diagnosis, prediction, and management of major dysfunctions of man. For example: in the study of oxygen toxicity the demonstrated pulmonary pathology is similar to that of emphysema, leading to the belief that this research may provide a laboratory model to study emphysema. Similarly, advanced bioelectrical techniques have led to a fuller understanding of man's balance mechanism, the vestibular system. New space monitoring and experimental techniques will help bring the practice of medicine-at-a-distance into reality for such applications as intensive care units, disaster-team operations, and medical care for remote areas that do not have the services of physicians. The derivation of simple methods for monitoring and predicting the future status of man's health, vital to space medicine, also is of vital interest in the general practice of medicine.

The optimum utilization of man in advanced space systems will be understood so that he can be assigned his proper role as an operator, a scientific investigator, a mechanic, and as a vital decision maker. This knowledge will be of benefit on earth with regard to the use of man for complex man/machine functions such as manufacturing, data processing and process control.

Small-group dynamics studies, associated with the long confinement of extended space flight, may well enhance our understanding of social problems on earth.

Advanced selection techniques and training methods for flight and operational crews will be applicable in both the public and private sectors of our society, particularly where high-risk operations are involved.

New regenerative methods for purifying the atmosphere and water in space vehicles will be applicable to the solution of pollution problems here on earth. For example, collaborative efforts are already underway with the Office of Saline Water and the Federal Water Pollution

Control Administration. This technology should make possible the development of individual home waste handling and water regeneration units that could eliminate the bulk of the domestic source of pollution to our waterways.

In the area of space foods, physico-chemical derivation of food from human waste could provide an additional means to combat food shortages in the world. Protective equipment technology, for space, will be applicable to industrial problems. For example, this technology can be utilized in the design of smokemask equipment for industrial use and for firemen, and in the design of life support and protective systems for other hazardous environments such as marine exploration.

Objectives

The ability to achieve the capabilities described earlier and to realize the associated benefits depend upon the extension of ground-based and space flight research. Expanded research activities in both of these environments requires the development of innovative instrumentation and data analysis techniques. In addition, significant advances in man's support, protection, and operational equipment are also needed to allow man to be utilized effectively. These needs have led to the development of the broad objectives for the Space Medicine Program, relating to biomedicine, man-systems integration, and life support and protective systems.

In the area of biomedicine the broad objective has been identified as follows:

1 - To determine the adaptiveness and tolerances of man to space operations, including a basic understanding of the fundamental mechanisms involved; to define the optimum physiological parameters for man; to assess his potential to function effectively in nonterrestrial environments; and to assure the functional integrity of man through the provision of appropriate protective and/or therapeutic measures.

This implies the need for in-depth studies on man himself and on other biological specimens, as may be required on the ground and particularly in space flight. Of special interest is the exposure of man to the space operational environment representative of future earth orbital, lunar, and planetary space exploration missions. Questions such as man's tolerance to atmospheres, gravity fields, and operational environments different from earth, have to be resolved.

The following specific objectives have been developed for this aspect of the program:

- Develop methods for assessing cardiovascular and musculoskeletal adaptation to acceleration, weightlessness and artificial subgravity states.

- Determine the qualitative and quantitative alterations evoked by space flight relative to hematologic, immunologic and biochemical parameters.

- Determine the implications of, and requirements for, various gravity levels for extended duration space flights and operations.

- Determine spacecraft atmosphere requirements for various space missions.

- Determine the effects of space flight on the respiratory physiological parameters, including dysbarism, maintenance of crew physical conditioning, and the assessment of the metabolic cost of physical activity at null and subgravity levels.

- Investigate and evaluate the effects of space flight on neurophysiological function including equilibrium, coordination, sleep, alertness, biorhythms, visual, and other special sense functions.

- Define the effect of space flight stresses on response of the endocrine system and develop the capabilities to use the endocrine system for measuring degrees of stress.

- Determine, detect, and control potential microbiological problems of man in closed or semi-closed ecological systems in spacecraft.

- Determine the space radiation effects and assess the hazard of space operations.

- Develop instrumentation of progressively increasing sophistication to permit required measurement of the various body systems and to provide a data management system.

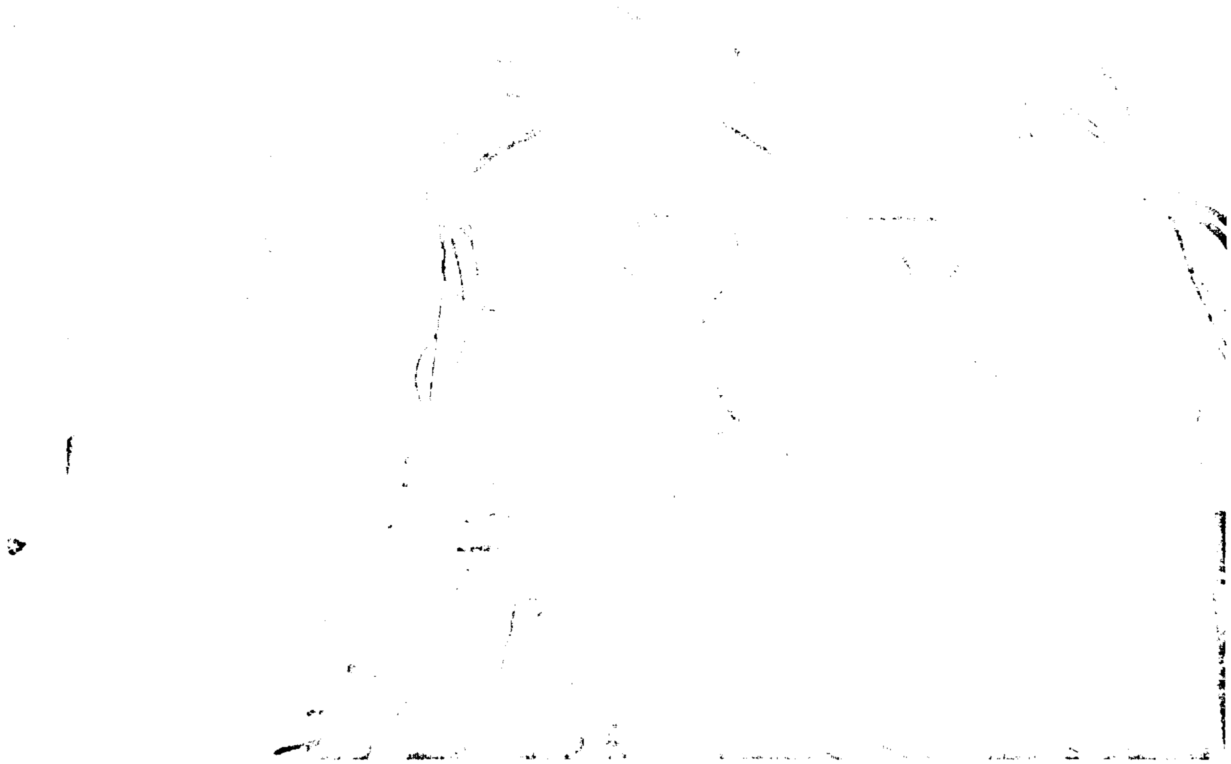
- Define and develop prediction, diagnostic, and therapeutic procedures, medication, and equipment to maintain the health and well-being of the crew.

- Determine the best use of pharmacology as a means to maintain the mental and physical integrity of man in the space environment.

EXPERIMENTAL SPACE SUIT FOR INVESTIGATION OF ADVANCED CONCEPTS

In addition to this information and technology, which will define the tolerance of man in space, a corollary requirement is to define man's capabilities. This leads to the following broad objective in the area of Man-Systems Integration:

2 – To determine the optimum uses of man's capabilities in space missions including the development of the techniques, technology, and equipment required for man to perform independently, or in cooperation with ground personnel, as a decision maker, a systems manager, an operator, and a scientific investigator.



NEUTRAL BOUYANCY TESTS ON UTILIZATION OF MAN FOR ERECTION OF STRUCTURES IN SPACE

Achievement of this objective will require ground-based and flight activity to develop concepts and supporting equipment relative to the capabilities and limitations of man in operational space systems. Development of these concepts and systems will be of particular importance for extended duration missions and missions that do not lend themselves to close support from earth. Of concern could be such items as tools for maintenance and repair, on-board data analysis, and resolution of man's capabilities and limitations related to the performance of useful work.

Activity in support of this broad objective would address the following specific objectives:

- Determine man's capabilities for performing physical and mental work as an operator and maintainer of space systems and equipment and as a scientific investigator, and to provide data for decisions on the appropriate mix of man and machine.

- Develop methods [illegible] crew selection, proficiency assessment [illegible] maintenance of skills, and trai[illegible]

- Determine man's individual behavior characteristics and group dynamics relative to space operations.

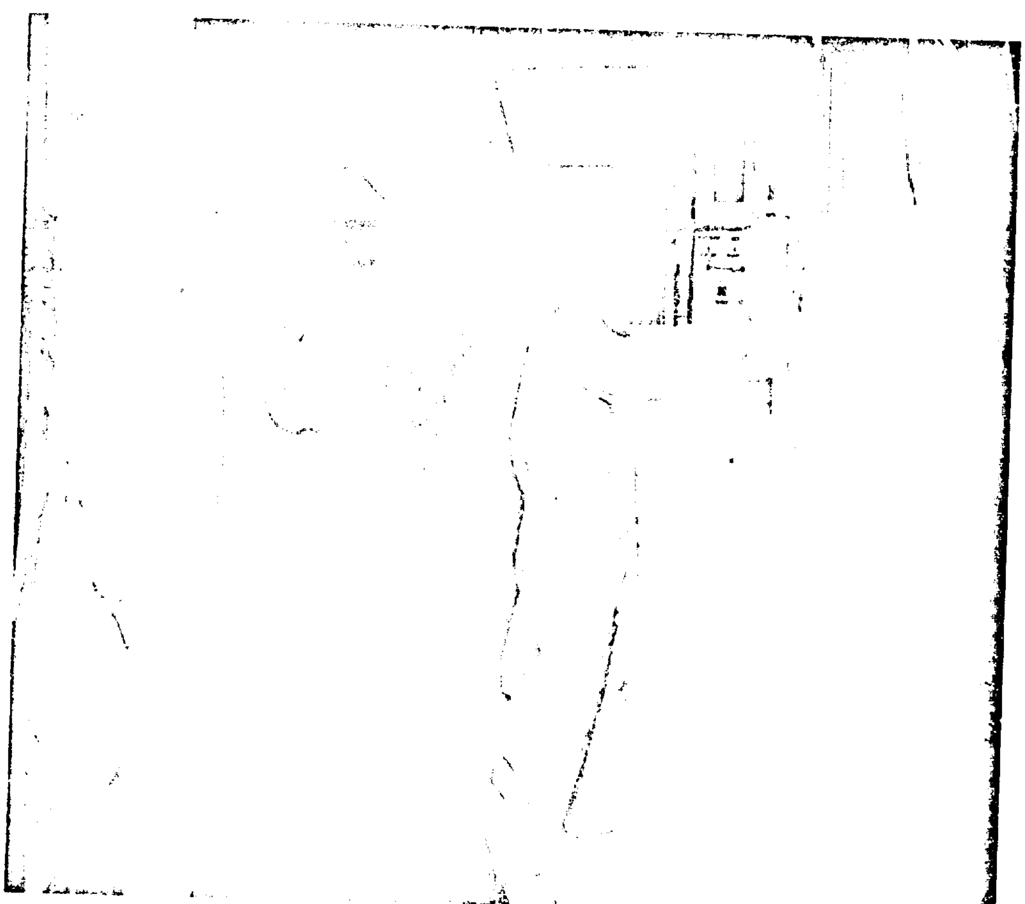
- Develop operator equipment and technology for crew and cargo transfer, assembly, and maintenance internal and external to the space vehicle and for operation on extraterrestrial bodies.

- Develop the technology for habitable living areas in space vehicles and on extraterrestrial surfaces.

In order for man to operate effectively in space, systems must be developed to maintain him in an environment that promotes his operating effectiveness. This requirement leads to the following broad objective in the area of Life Support and Protective Systems:

3 - To develop the technology for highly reliable systems that will support and protect man and enhance his capability to perform space flight operations and to perform on extraterrestrial surfaces.

This broad objective implies the development of major life support and protective systems such as atmospheric controls; water and waste management; food storage, generation, and preparation; space suits; and mobility equipment. Here again an aggressive ground-based program is indicated backed up by flight activity on critical long-lead items. Specific supporting objectives are:



EXPERIMENT ON OXYGEN AND WATER REGENERATION FOR LONG DURATION LIFE SUPPORT SYSTEM

- Develop technically and esthetically satisfactory techniques and hardware for providing personal accommodations in the areas of food management, personal hygiene, and waste management; develop techniques and hardware for the reclamation and sterilization of potable water from waste waters such as urine, wash water, and humidity condensate; and develop the technology to convert metabolic wastes into food.

- Develop techniques and hardware for storing, dispensing, and conserving oxygen and diluent gases and for regenerating oxygen and diluents (e.g., nitrogen) for extended mission durations. In addition, develop techniques and hardware for controlling the carbon dioxide, humidity, and contaminant characteristics of the cabin atmosphere.

- Develop thermal control techniques for environmental thermal control/life support system (ETC/LS). Specifically, this includes the techniques for: (1) Providing thermal energy used in reclamation processes and, (2) removing and rejecting waste heat from the atmosphere, the ETC/LS subsystems, and the electronic and experimental equipment.

- Develop the instrumentation for monitoring and controlling the atmosphere composition, thermal environment, chemical and microbial contaminant levels, and system functions to ensure a safe, comfortable, and efficiently operated habitable spacecraft.

- Define the technical and practical problems of, and provide solution options for, combining individual processes and hardware elements into an efficient, integrated ETC/LS systems that would satisfy the requirements of various classes of missions.

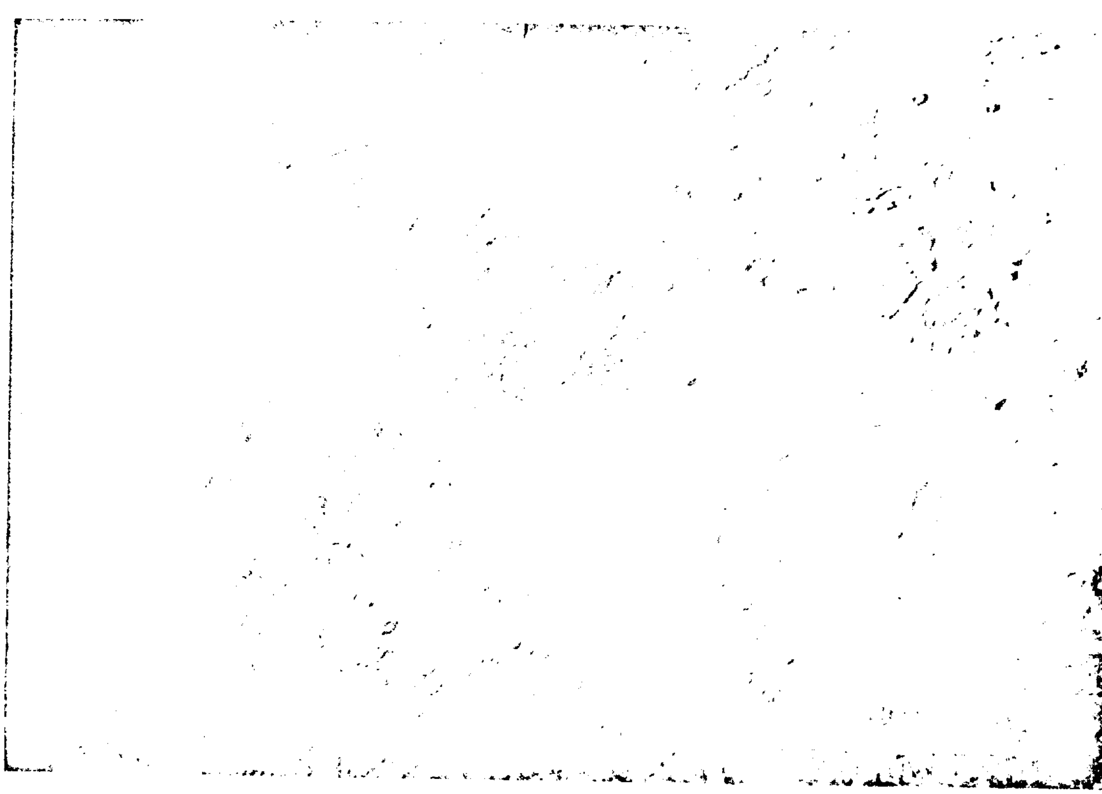
- Develop the garments, portable ETC/LS systems, and other aids for enabling the astronauts to perform the necessary intravehicular activity tasks.

PLANETARY EXPLORATION

Throughout history, men have observed the planets from the earth. Based on these observations, many characteristics of each planet and the interrelationships of the planets were either measured or derived. However, the inadequacy of the data led to conflicting theories. With the advent of the space program, man now has the capability to obtain detailed measurements which will test old theories, lead to new theories, and will answer century old questions about the planets. Observations with spacecraft have already been made of the nearest planets, Venus and Mars. Also ground observations of all of the planets have been improved by new techniques and facilities.

The flight program to investigate Venus has consisted of one flyby mission in 1962 and a second one in 1967. The observations made during these missions indicate that Venus has a surface temperature over 600 degrees Kelvin and an atmospheric pressure as high as 100 earth atmospheres. The composition of the atmosphere is predominantly carbon dioxide with minor amounts of oxygen, water, and nitrogen. An absence of a strong magnetic field about the planet suggests that the core of Venus is considerably different from the core of the earth.

In 1965, during a flyby mission to the planet Mars, the first close-up photographs of another planet's surface were transmitted to the earth. The photographs revealed the presence of craters ranging up to 150 miles in diameter. From the telemetry signal as the spacecraft passed behind the planet the atmospheric pressure was determined to be about one percent of that on earth, considerably lower than had been surmised. The two Mars flyby missions in 1969 provided higher resolution photographs, atmospheric pressure measurements with improved accuracy, measurements of the atmospheric composition, and surface temperature.



SOUTH POLAR CAP OF MARS

The current program places a high priority on Mars exploration. There are plans for two Mars Orbiters in 1971 and two Mars Lander/Orbiter missions in 1975 with the Viking spacecraft. The 1971 Mars Orbiters will be our first spacecraft to orbit another planet and will obtain visual and infrared mapping of the surface. The 1975 Mars Lander will provide our first opportunity to discover life, should any exist, on the planet Mars. In addition, the Lander will be able to obtain in situ measurements of the atmosphere and surface environment.

While the current program stresses Mars, it also includes missions to three other planets. In 1973 a spacecraft will be launched to fly by Venus, taking the first television pictures of that planet, and then proceed on to Mercury to take pictures of the surface and to measure that planet's basic characteristics. A pair of spacecraft are also being developed for launch to Jupiter in 1972 and 1973. These spacecraft will make important measurements in the Asteroid Belt in addition to transmitting images, environmental data, and atmospheric properties from Jupiter. A new spacecraft is being designed for a 1974 launch to probe within 0.3 AU of the sun. This is a joint project with West Germany in which that country will design and develop the spacecraft.

Goal

Correlation of the results from the above missions with results obtained from interplanetary spacecraft, ground telescopes, and earth-orbiting observatories will provide the first step toward the goal of Planetary Exploration, which is:

- To understand the origin and evolution of the solar system, the origin and evolution of life, and the dynamic processes that shape man's terrestrial environment.

Possible Future Achievements

It is technically feasible for the Nation to achieve by the mid-1980's the following positions through aggressive pursuit of the above goal:

- Visit and photograph all known planets.
- Answer the question, "Is there life elsewhere in our solar system?"
- Develop a broader understanding of the earth and life on earth through comparative studies with the other planets.

By its very nature, planetary exploration provides an outlet for man's inherent desires to explore the unknown and to achieve. In addition to satisfying the desires of the explorers themselves, planetary exploration can inspire all mankind as the program progresses from planet to planet. The expanse of the solar system will be viewed in detail when the photographs and other data are returned to earth from the surface of Mars and from the vicinity of the other planets of our solar system. Further, the discovery of life elsewhere in the solar system or a full explanation for why life exists only on earth, has been described as potentially the most significant scientific advancement in this century.

This generation has a great opportunity to make significant contributions to the scientific understanding of the solar system in which we live. One exciting prospect of using such knowledge is the improvement of our understanding of the earth and life on earth, its past and future, and the relationship of earth to its environment. Comparative studies between the planet earth and the other planets may help us to understand and control our atmosphere and to more accurately predict earthquakes, as only two examples. A better understanding of life and its origin may have untold benefits to life on earth.

In the past century, the economy of the United States has become strong and increased its standard of living by being on the forefront of technology. History has clearly shown that the advancement of technology requires a focus or forcing function. Because of its advanced nature, planetary exploration is an ideal stimulant to forcing advances in technology. The use of man himself in such missions will provide a direct focus for technology advances in biomedicine, long-life reliable equipment, and nuclear propulsion, to mention only a few. Further, sending man to explore beyond the moon, first to the planet Mars, will remove the concept that man is restricted in his capabilities to perform personal exploration deep into space, and will open his thinking to the possibility of manned exploration of the complete solar system.

THE SOLAR SYSTEM

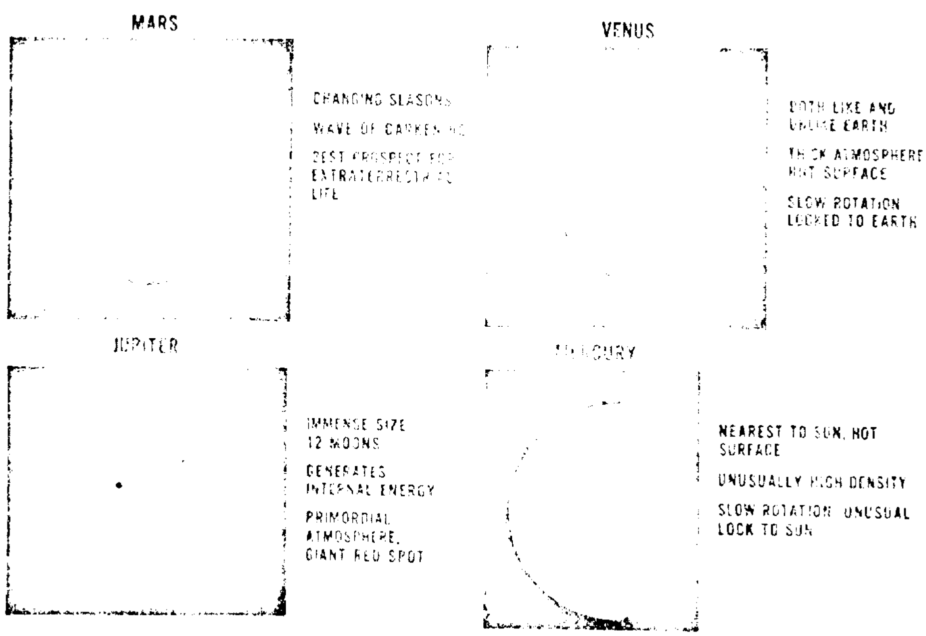
Objectives

To achieve the goal of Planetary Exploration, data must be gathered so that man can understand the origin and evolution of earth and the solar system; to provide a better understanding of the processes which are continuing to affect the earth and its environment; and to determine the origin and evolution of life. The pursuit of this knowledge has been categorized into five broad objectives, the first of which is:

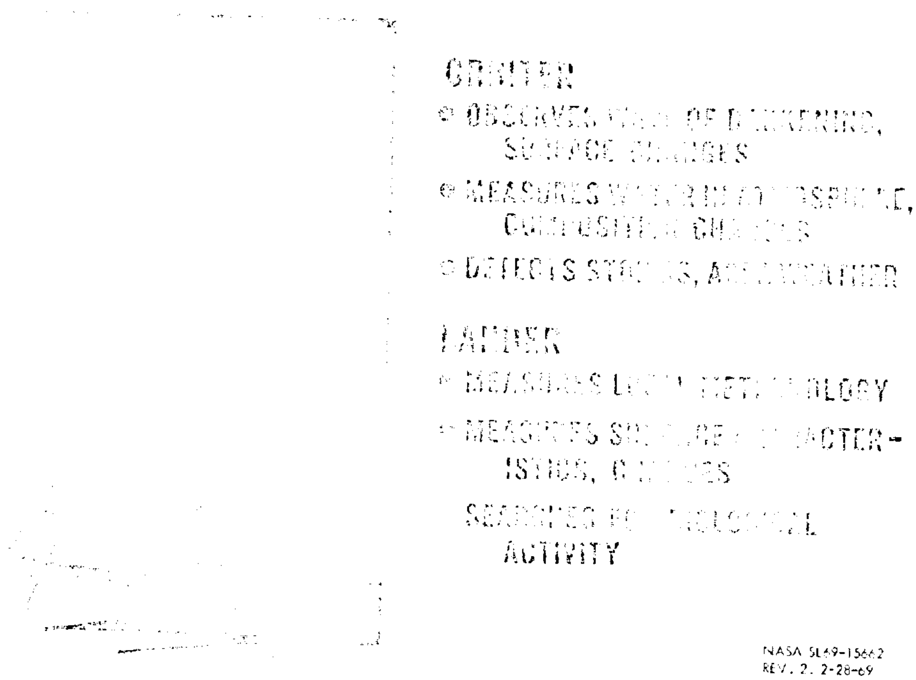
1 – Determine the environment, atmospheric properties, surface characteristics, and body properties for each planet; determine the sun-planet relationships and dynamic processes for the various planets.

This objective implies making detailed scientific investigations of all the planets in our solar system. Each planet must be investigated as each has its own particular characteristics, such as the seasonal wave of darkening of Mars, the Red Spot of Jupiter, the rings of Saturn, the clouds of Venus, the tilted spin-axis of Uranus, the unusual moons of Neptune, and the exceptional orbit of Pluto. The investigations will be designed to develop data on the current external and internal structure; major surface features and their origin; chemical composition and variations as related to major surface features; the atmosphere, if any; the seasonal and diurnal variations; and the near space environment. In addition to the examination of the planets themselves, specific investigations will be conducted on the satellites of the planets, which have their own unique characteristics.

In the section that follows, the unique characteristics of each planet and other interplanetary bodies are described, following which the specific objectives related to that planet or body are indicated.



SOME PREDOMINANT FEATURES OF THE NEAR PLANETS



EXPLORATION OF MARS BY AN ORBITER AND A LANDER WORKING AS A TEAM

Mars

Mars has an atmosphere which has probably evolved quite differently from that of the earth, thus knowledge of its dynamic properties will be useful in fully understanding our own atmosphere. Mars has little or no magnetic field. As a consequence, the interplanetary medium reacts much more intimately with the planet than is the case for earth.

- Identify the major characteristics of the atmosphere, including the molecular and isotopic content (the latter is important to determine the origin of the atmosphere); the atmospheric circulation and its driving forces; the composition and generation of the different types of clouds; the interaction of the atmosphere with the polar caps; and the diurnal and seasonal variations of the atmospheric properties.

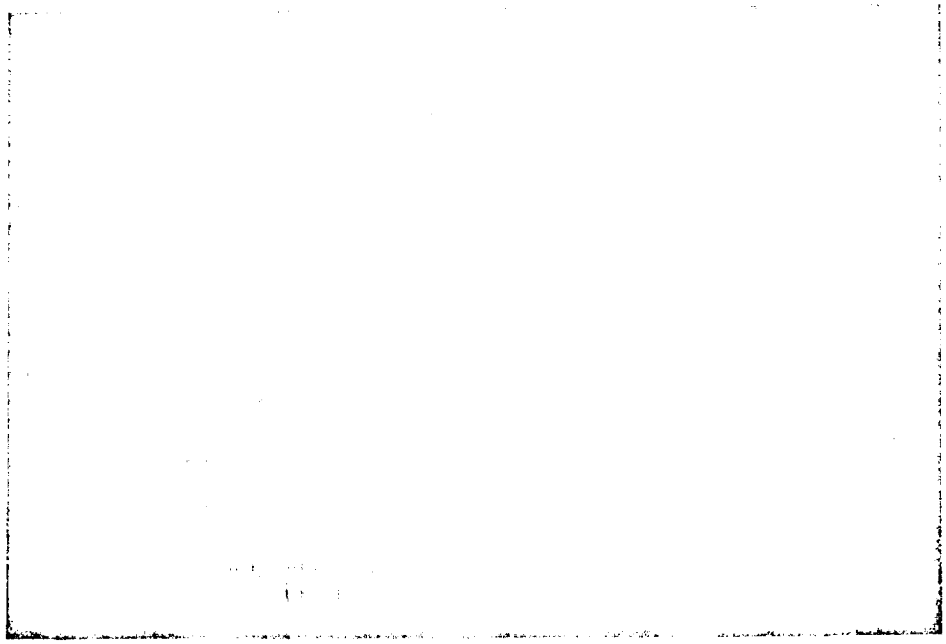
- Determine the mechanism of the seasonal wave of darkening.

- Define the topography and surface mineralogical composition, identify the major subsurface geological units, and define the erosion and weathering mechanisms.

- Determine the internal characteristics, the primary elements of which are mass distribution, the presence and extent of a core, and internal activity.

- Define the solar/galactic flux interactions with the planet, the primary features of which are the principal ionized and nonionized species, the reaction kinetics and the dynamic properties of the ionosphere, and the solar plasma/atmosphere interaction.

- Determine the surface features, the surface composition, and the rotational parameters of the satellites Phobos and Deimos.



SPACECRAFT FOR VENUS-MERCURY FLYBY

Venus

Venus is nearly a twin to the earth in size but has a far more dense atmosphere and an unusual rate of rotation, which is apparently related to the orbiting of the earth around the sun. No magnetic field has been detected, so the solar wind can presumably interact directly with the atmosphere.

- Determine the characteristics of the atmosphere, including:
  - Composition, both molecular and isotopic.
  - Distribution and chemical composition of the clouds.
  - Sources of opacity.
  - Vertical temperature and pressure profiles.
  - General circulation pattern.
- Define the various heat sources, both atmospheric and surface, and identify the surface heating mechanism.
- Define the topography and composition of the surface, and the interaction between the atmosphere and surface.
- Define the internal mass distribution and gross figure of the planet, identify the magnitude of the magnetic field, and determine the extent and nature of internal activity.
- Define the solar wind interaction with the atmosphere.

Mercury

Mercury is interesting because of its closeness to the sun, its unusual spin/orbit coupling of three revolutions for every two orbits of the sun, and its relatively high density. With little or no atmosphere, the effect of solar radiation on the planet is probably maximized.

- Define the composition, topography, geological structure, and temperature variation of the surface.

- Identify the body characteristics, mass distribution, and internal structure.

- Define the solar wind interaction with the planet, and determine the presence and magnitude of a magnetic field.

- Determine the presence of an atmosphere or ionosphere; their composition and the mechanisms maintaining them.

Jupiter

Jupiter, the nearest of the major planets and the largest of all planets, has a low density and may be comprised of the basic materials from which the solar system bodies were first formed. It appears to radiate more total energy than it receives from the sun. The coloration of the atmospheric belts and of the famous Red Spot is suggestive of complex organic molecules. Jupiter has an intense magnetic field and emits strong RF radiation.

- Determine the energy balance.

- Define the fields and RF radiation sources.

- Define the solar/galactic flux interactions with the planet.

- Determine whether the interior of the planet is liquid or solid, and the origin of the magnetic field.

- Determine the composition and physical state (gas, liquid, solid) of the atmosphere and its aerosols, the hydrogen to helium ratio, and the isotopic distribution.

- Define the dynamical processes acting in the atmosphere.

- Determine the dynamics and composition of the Red Spot, with emphasis on any complex organic molecules; determine its mechanism of formation.

- Determine the nature of the satellites, their atmospheres, surfaces, and interiors.

GRAND TOUR SPACECRAFT FOR OUTER PLANET EXPLORATION

Saturn

Saturn is a huge planet, second only in size to Jupiter. It is the only planet known to possess rings. It is also the only planet difinitely known to have a satellite with an atmosphere (Titan).

- Determine the composition and structure of the atmosphere.

- Determine the internal mass distribution; identify any magnetic field and determine its magnitude.

- Define the interaction of the solar wind and galactic radiation with the planet; determine the nature of any radiation belts.

- Determine the characteristics of the rings. The primary elements of interest include: mass distribution, particle size distribution, composition, and the basis of the uniqueness of the rings to only one planet in our solar system.

Uranus and Neptune

Uranus and Neptune, like Jupiter and Saturn, are characterized by their large masses and small mean densities. Uranus is unusual in that its rotational axis is almost in the plane of the ecliptic. Neptune has a large satellite, Triton, with a retrograde orbit and possibly with an atmosphere.

- Determine the composition and structure of the atmosphere.

- Determine the internal mass distribution; identify any magnetic field and determine its magnitude.

- Define the interaction of the solar wind and galactic radiation with the planets; determine the nature of any radiation belts.

Pluto

Pluto is the farthest planet from the sun and the most recently detected. Because of its great distance from earth our knowledge of its properties is slight. Present data indicate its size is about that of Mercury, while its density is about 50 percent higher than either Mercury or earth.

- Determine the composition and structure of the atmosphere.

- Determine the internal mass distribution; identify any magnetic field and determine its magnitude.

- Define the interaction of the solar wind and galactic radiation with the planet; determine the nature of any radiation belts.

- Determine the size and average density.

Comets

Comets are radically different from other solar system objects in their unique physical makeup, usually consisting of a small bright nucleus, a diffuse "coma" surrounding the nucleus, and, when near the sun, a tail extending millions of miles generally in the anti-solar direction from the head of the comet. Orbits of comets are usually highly eccentric, which often carry comets far outside the bounds of the solar system. Observations of comets may give clues as to conditions existing at extreme distances from the sun, which in turn would aid in unraveling the origin and nature of the solar system.

- Study the composition and physical state (gas, solid) of typical comets.

- Study the interaction between the solar wind and comets.

- Study cometary dynamics--release of gases and particles from the nucleus and their escape.

Asteroids

Asteroids are fragments of material which exist largely in a belt between Mars and Jupiter. They may be the result of the collisions and breakup of planets, or they may be the debris that was left over when the terrestrial planets formed.

- Define the three-dimensional distribution of matter in the asteroid belt.

- Determine the surface features and composition, densities, and rotation periods of typical asteroids.

- Determine age, previous condition (whether exposed to extremely high pressures or not), and other properties that will shed light on whether the asteroids are remains of a planet that broke up or are material of the sort that accumulates to form a planet.

The understanding of the planetary properties from the pursuit of the above objectives will describe environmental conditions that could indirectly indicate the probability of current or prior life forms. A more specific investigation of the intriguing possibility of finding life existing on another planet of our solar system leads to the next broad objective:

2 - Determine whether life exists elsewhere in the solar system, whether it might have existed and no longer does, whether or not conditions are suitable for the development of life, and if not, why they are not. If life forms are found, categorize and compare them with life on earth.

This objective requires a continuing search for organisms in living and/or fossil forms. The search will be conducted primarily on the planet Mars while the data from the other planets will be studied to determine whether the environment may now or could have ever supported life. In addition to direct life detection, investigations on Mars will include observations of surface environment, surface material analysis, and studies of the atmospheric characteristics for an indication as to whether it would be possible for the planet to support life. If no evidence of life is found, it will be important to gather data to obtain a full explanation of why life exists only on earth. The results of the analyses of these data, in context with information on the history of the planet, will then be tested against current theories on the mechanisms related to the evolution and origin of life.

All data from each of the specific objectives listed above under the first broad objective must be studied by biologists since the data could indicate the possibility of life forms being present. In addition, for the planet Mars the following specific objectives apply:

- Search for and characterize living and/or fossil organisms.

- Determine the presence and characteristics of organic matter, and whether it is biogenic or abiogenic. If no life is detected, ascertain whether prebiotic, chemical evolution is occurring.

- Identify major characteristics of the surface environment, in particular the moisture distribution and thermal anomalies, and the variations of these properties with latitude, longitude, and season to permit the selection of sites at which life would be most likely to exist on the planet.

- Search for minor atmospheric constituents of possible metabolic origin.

- If no life [illegible], either living or extinct, are detected, ascertain the reason [illegible]y.

Observations made during the exploration of the planets will be aimed at obtaining data that provide specific elements of information or answers to specific questions. However, the unique assemblage of such data will also prove valuable for making correlative or comparative analyses of the various objects in the solar system. It is thus important to also use the data for these purposes. This need to capitalize fully on the data obtained during exploration of the planets and other bodies in the solar system leads to the following broad objective:

3 - Make comparisons of the physical, biological, and other characteristics of the various objects in the solar system, including planets and their satellites, comets, and asteroids.

Already, new knowledge of the other planets has substantially increased our understanding of the earth and its dynamic processes (e.g., atmospheric heating). It is the comparison of the similarities and differences among the planets that provides a great stimulus to the development of theories on the origin and evolution of the solar system. The interplanetary comparisons must be accomplished in all scientific disciplines and across the various disciplines. Some of the disciplines most involved will be in the areas of physics, biology, geology, and meteorology. This type of analysis will provide the testing ground for existing and new theories of the origin and evolution of life, the origin and evolution of the planets and the solar systems, and the dynamic processes which continue to affect planet earth and to shape man's environment.

Achievement of this objective leads to the following specific studies:

- Conduct comparative studies in each scientific discipline as data become available.

- Conduct comparative studies on an overall planet basis as data become available.

Previous objectives dealt with the exploration of those planets and bodies in our solar system which are known. In contrast, the following broad objective relates to planets and other bodies yet to be discovered in the solar system:

4 - Determine the true extent of our solar system and search for evidence of undiscovered objects in our solar system.

This objective involves a close scrutiny of all data as they become available to search for clues which will give an indication of bodies in space that are not yet discovered. Pluto was discovered within the last 40 years, and a new satellite of Saturn was found in the last five years. A new comet was discovered within the last two years, and only a relatively few of a potentially vast number of asteroids have been recorded. Therefore, it is both possible and likely that there are additional planets in our solar system, as well as undiscovered moons of the planets, especially the outer planets.

The following studies of planetary data should be made to enhance the possibility of such new discoveries:

- Analyze available data for undiscovered planets.

- Determine the existence of additional bodies by studying data obtained while exploring all of the planets of our solar system.

The planetary program in the past has been and in the near future will be conducted with automated spacecraft. However, the possibilities of utilizing man as an on-site explorer has many advantages. The development of flight systems and man's capabilities to operate in earth-orbit and to explore the moon are necessary precursors leading to manned exploration of the planet Mars. The concept of man as a planetary explorer is reflected in the following broad objective:

5 - Utilize the unique capabilities of man for in situ exploration of the planet Mars.

This objective implies in situ measurements utilizing the capabilities of man. These investigations will verify and extend the measurements obtained by automated spacecraft, utilizing man's incomparable talents to recognize and adapt to the unexpected. Man-tended instruments with adjustable scales can increase the accuracy of the data. Man can perform immediate analyses of data and modify measurements or observations as appropriate. Man can select the best sites for his own measurements and sample collections, and for implacing automatic scientific instruments for long-term data collection and data transmission direct to earth. Analyses of surface material can be conducted during the return trip to earth.

CONCEPT OF MAN'S INITIAL LANDING ON MARS

To realize this potential that man offers in the exploration of Mars, various capabilities must yet be developed to prepare man and manned systems to meet the demanding requirements of long planetary flight. Considering such yet-to-be developed capabilities and the in situ measurements to be made, the following specific objectives have been defined leading to the utilization of man in the exploration of Mars:

- Establish the capability for man to exist and to perform useful functions in the environment of space over periods up to three years.
- Develop and qualify long-life systems and subsystems required to support manned exploration missions.
- Develop and qualify key techniques and systems such as: launch vehicles, earth reentry, planetary entry and escape, communications, guidance and control, and spacecraft power, utilizing the capabilities and systems developed in manned earth orbit and lunar flight activity.
- Acquire data on interplanetary and planetary environment for design and operation of space systems. These data will include:
  - Micrometeoroid and radiation environment.
  - Characteristics of the planetary ionosphere, atmosphere, and surface including dynamic characteristics and seasonal variations.
  - Geophysical characteristics of the planets.
- Develop sterilization techniques and quarantine techniques to minimize the contamination of the planets and the back contamination of the earth.
- Collect surface samples, perform immediate analysis, and return samples to earth.
- Make personal and direct measurements of the atmosphere and surface characteristics.
- Select sites for emplacing automated scientific stations and adjust the range of instruments as appropriate, for data collection while present, and for subsequent data transmission directly to earth.
- Modify the scientific measurement program based on immediate analysis of acquired data.

ASTRONOMY

For centuries man has been studying the stars which have been emitting light energy and heat energy for billions of years. Until recent years, access to the stars, nebulae and galaxies lay entirely through the fluctuating beams of light and other radiations that filtered through the earth's thick uneven atmosphere.

With the advent of sounding rockets and orbiting satellites, great new vistas opened before us as it became possible to send observing equipment above the obscuring and distorting atmosphere to observe the universe in all the wavelengths that reach the top of the atmosphere. This exposure to the entire spectrum of electromagnetic radiations has given special impetus to the science of astronomy by transforming astronomy from a data gathering activity to one of problem solving. However, to capitalize on this new capability has required some difficult and complex engineering and technical advances. The first major step was the creation of the Orbiting Solar Observatory, designed for gathering information on the sun, followed several years later by the Orbiting Astronomical Observatory, destined to look at the stars. Although the observations made over the past ten years using sounding rockets and Explorer class satellites have provided some significant results, now with the Orbiting Astronomical Observatory, joining the Orbiting Solar Observatory, many remarkable results are being obtained.

The principal discoveries that have been made to date in the space astronomy program are:

- Discovery of X-ray emissions from various regions of the sky.
- Discovery that the center of our galaxy is a source of gamma rays and that it is surprisingly bright in the infrared.
- Detection and survey of ultraviolet and soft X-ray energies coming from the sun.
- Discovery of radio signals coming from the earth that are similar to radio waves coming from the planet Jupiter.
- Discovery that the hottest stars in the heavens are even hotter than suspected.
- Information suggesting that normal galaxies are unexpectedly bright in the ultraviolet region of the spectrum, which may explain some of the very blue objects which have been discovered in our search for quasars. If this phenomenon is as common among the distant galaxies as in those near to our galaxy, its discovery may have significant cosmological consequences.
- Clues as to the composition of the fine cosmic dust floating through space that might tell us how the earth was formed.

THE MILKY WAY, SOLAR SYSTEM, AND NEIGHBORING STARS

Goal

The current Astronomy Program includes spacecraft that will continue to survey and study the bright, the faint, the relatively near, and the very distant celestial objects. These spacecraft will survey the sun with increased resolution, and will observe and study high energy X-rays and gamma rays, ultra-high energy cosmic rays, and the nature of the physical processes occurring at the sources of these energies. The program envisions the use of both automated and manned systems throughout the next decade. The results of these missions when complemented with the results of ground-based astronomy will add another incremental step toward the goal of Astronomy, which is:

- To understand the origin and continuing evolution of the cosmic environment, by observing and interpreting the basic physical processes in our solar system, stars, galaxies, and the universe.

Possible Future Achievements

In the process of advancing our knowledge and understanding of the space environment and the universe in pursuit of the goal, it is entirely possible for us to realize four major achievements by the mid-1980's, provided we pursue an aggressive research program. These achievements and their significant values are described in the following discussion.

The first of the four potential achievements is:

- To have an understanding of the most important aspects of the sun and our solar environment.

A program of observations of the sun from space will enable us to understand the major phenomena of the sun which affect the earth's environment, and to be able to predict the occurrences of these phenomena. Since the sun is our nearest star, by understanding the sun's major phenomena, we will be able to increase our understanding of other stars, and add to our general knowledge of energy conversion mechanisms.

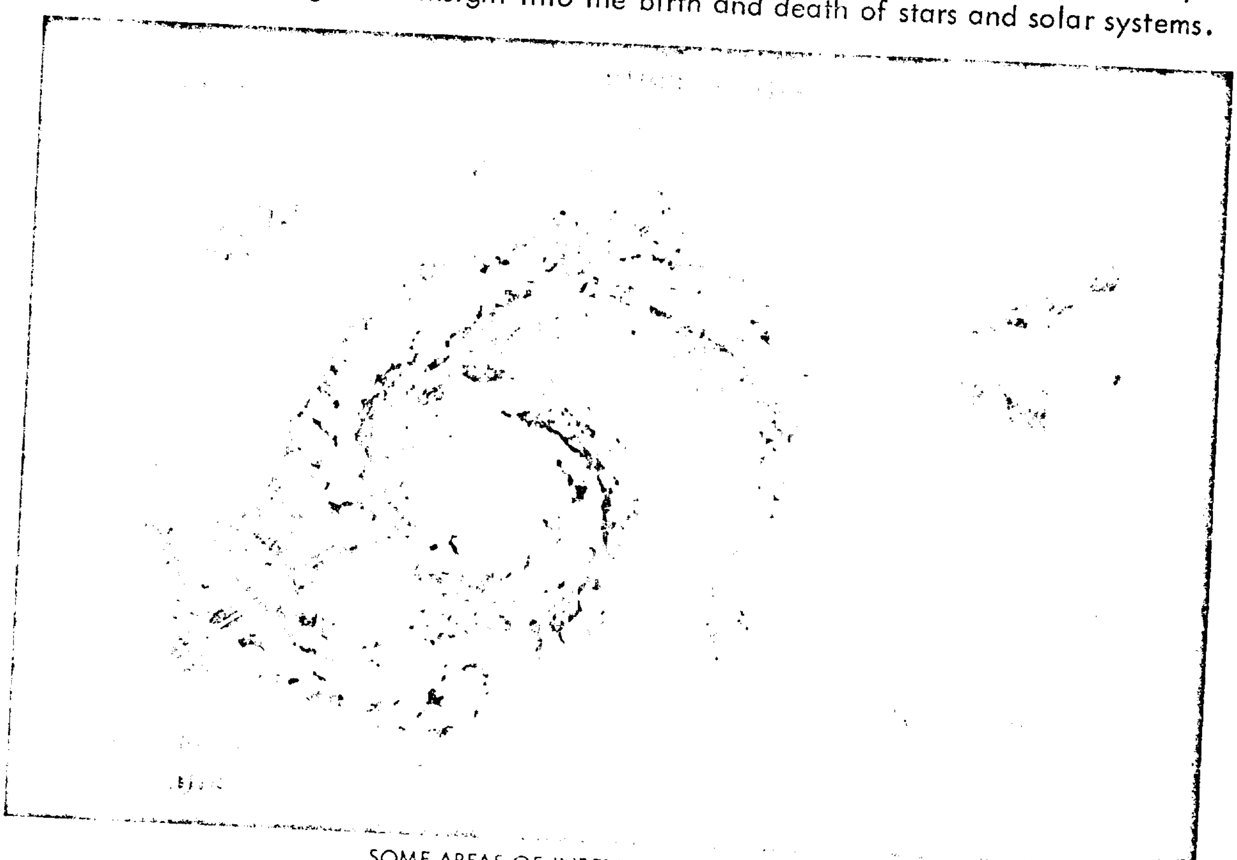
This understanding, together with associated studies, will contribute directly to our knowledge of the solar heating of the earth's upper atmosphere and its correlation with weather and suspected periodicities (e.g., rainfall). Solar observations will likewise provide a knowledge of the radiation hazards from solar flares which is important to the design of manned and automated spacecraft and to high flying aircraft of the near future. Our understanding of the sun and its major phenomena will also enhance applications of communication and radar systems that require a knowledge of ionspheric perturbations and change, as well as navigational systems that are dependent on the earth's magnetic field.

A second possible major achievement attainable by the mid-1980's is:

- To have an understanding of stars and our cosmic environment.

A program of observations from space is required to understand the stars and other objects in the universe, the matter and force fields between these objects in space, and their interactions. Just as observations and studies of the sun help us understand stars, so do observations and studies of stars help us understand the sun. There are young stars and old stars, hot stars and cool stars. Studies of these will tell us how our sun looked in the past and how it will evolve in the future.

There is evidence that half the mass of our galaxy, the Milky Way, is not in stars but in the dust and gas between the stars. The determination of the composition and distribution of this material is crucial to our understanding of the formation and present environment of our solar system. Since stars are likely to be formed from this dust and ultimately explode back into dust, the study of this matter can give us insight into the birth and death of stars and solar systems.



SOME AREAS OF INTEREST IN ASTRONOMY

However, to approach an understanding of the vast physical universe in which the earth is located requires that we obtain answers to many sweeping and challenging questions, such as: What are the large scale characteristics of the universe? Did it originate with a big bang? Is it being continuously created? Is it open or closed? How did the universe begin, and evolve? How will it end?

Substantial progress can be made in answering these questions by observing faint and distant stars and galaxies with large space telescopes that can effectively bring all galaxies in the universe ten times closer than is possible with ground-based instruments. Space telescopes of this type will allow us to make more accurate measurements of the distances to remote galaxies. When these measurements are related to previously observed velocities indicating the expanding nature of our universe, we will obtain accurate values of the Hubble constant (the ratio between expansion velocity and distance). This constant, along with other information such as the age of the stars in these galaxies, will help us determine the time since the creation of the universe, and the large scale past, present, and future characteristics of the universe.

A further possible achievement is:

- To have permanent national astronomical space observatories.

Space observatories with a variety of astronomical telescopes, some with capabilities far exceeding those of present day earth-based telescopes, will make possible observations above the obscuring effects of the earth's atmosphere and in essentially all wavelengths of light. These observations will make a dominant contribution to our understanding of the content, structure, and evolution of the universe.

Development of observatories with large astronomical telescopes will result in the extension of our technical capabilities in the area of large precision optics, detectors for X-ray, ultraviolet, and infrared light, and stabilization and control systems. This technology has a broad range of utility, and will be required for satellite systems designed for a variety of earth-oriented applications.

National astronomical space observatories will also provide a unifying force in astrophysics and maintain United States preeminence in the field of astronomy. As an immediate practical value, such observatories will encourage and maintain the support of the youth of our country and the world for the United States as an imaginative, innovative leader in the peaceful uses of science and technology.

The final achievement that we visualize as being realized by the mid-1980's is:

- To have made major discoveries equivalent to our understanding of nuclear processes in the sun.

Astronomy is the science that has provided man with the fundamental laws of celestial mechanics, gravity, mathematical concepts of integration, time, and computers, and gave impetus to the development of the basic concepts of nuclear energy. It expanded man's view of his neighborhood beyond the earth, to the solar system, to other galaxies, and to the awesome scope of the universe. The frustrations of youth are related to the confinement of our sphere and to their need for new frontiers and challenges; astronomy can provide new opportunities. In a nutshell, our increased ability to observe other objects in the universe above the obscuring effect of the earth's atmosphere promises to expand our horizons outside the boundaries of man's "spacecraft," the planet Earth. An example of discovery is the expectation that space astronomy will allow us to determine whether earth-like planets exist outside our solar system. On a vastly different front, we seek to discover how recently-observed pulsars can apparently emit energies at a rate 50,000 times that of our sun, and to determine what this may mean to man's use of energy here on earth.

Objectives

To achieve these capabilities by the mid-1980's requires a broad cohesive program of scientific research. The data gathered by this program of scientific research will also materially contribute to the attainment of the six broad objectives established for Astronomy. For instance, in our efforts to understand the physics underlying solar behavior and the effects of the sun on man's technology and environment, we are led to the first broad objective:

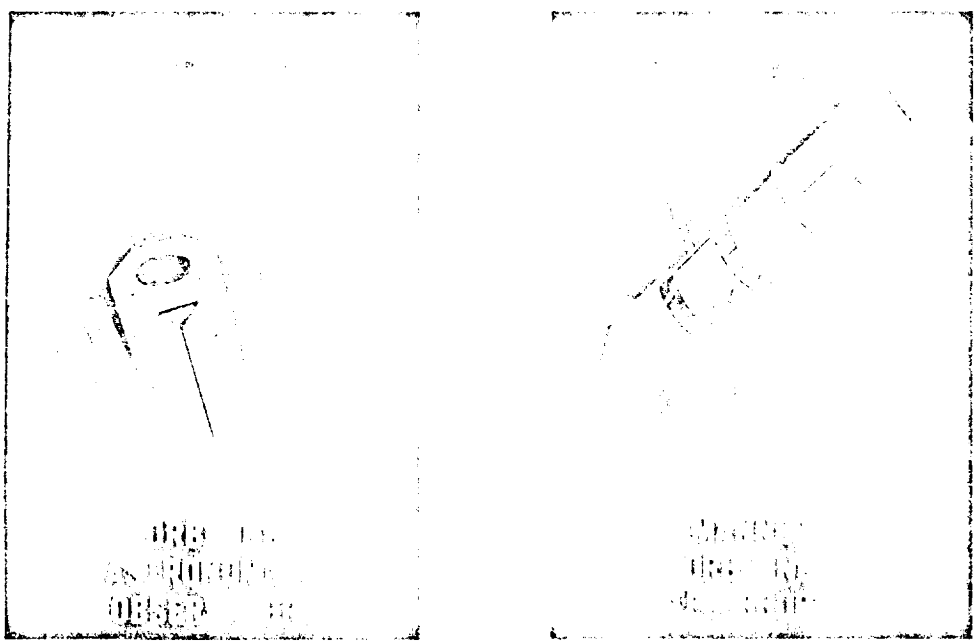
I - Develop a satisfactory model of the structure and physics of the "quiet" sun and of the processes involved in solar activity.

Achievement of this objective implies the acquisition of solar data over the entire electro-magnetic spectrum from low frequency radio waves to energetic gamma rays on the order of 200 kilovolts. This broad spectral range should be observed simultaneously with the highest possible spectral, spatial, and time resolution over long periods of time. Concurrently, there should be measurements of the solar particle radiations emitted into the solar wind, and the magnetic structure of the solar wind as related to the solar magnetic fields. This latter set of observations is particularly important from the point of view of understanding the physics under-lying solar activity. Furthermore, there needs to be long term ground-based and space observa-tions of the morphology of solar features and realtime measurements of solar magnetic fields. These observations should be performed with instruments that provide the highest spatial resolution. Of equal importance is concurrent laboratory work to permit a proper physical identification and interpretation of solar observations and of theoretical work to integrate all the observations, including laboratory studies.

Based on the type of information needed to achieve the preceding objective, the following specific objectives have been established:

- Develop a satisfactory model of the quiescent solar corona.
- Develop a satisfactory model of the chromosphere-corona transition region for the quiescent sun.
- Determine the abundances of the elements as functions of height in the solar atmosphere.
- Determine the cause of the stability of the photospheric intergranular structure.
- Develop a detailed description of coronal streamers and their relation to coronal prominences.

- Identify the physical mechanism giving rise to spectral lines seen only in flares.
- Improve correlation of solar transient phenomena with their terrestrial effects.
- Determine effective kinetic temperature structure in flares from shapes of extreme ultraviolet spectral lines.
- Improve reliability of solar flare prediction techniques.
- Determine the true level of solar X-ray continuum radiation and its emission mechanism.
- Search for thermonuclear reactions during phases of solar activity.



THE EVOLUTION OF SPACE ASTRONOMICAL OBSERVATORIES

By observing and interpreting the physical processes occurring on planets and other cool members of the solar system, we believe we can begin to understand the origin and evolution of our own planet. This leads to the following broad objective:

2 - Study important processes occurring on planets and other cool members of the solar system through observations from the vicinity of the earth.

This objective implies repeated photographs of the planets in the visible, ultraviolet, and infrared regions of the spectrum with the highest spatial resolution available. It also implies repeated spectral measurements in these regions with both moderate and high resolution. Moderate resolution visual imagery and some visible and infrared spectroscopy can and should be done from the ground and from balloons and airplanes. Long-wave radio receivers, with sufficient spatial resolution only to distinguish one planet from other planets and from other sources such as the sun and galaxy, should monitor radio bursts from Jupiter and possibly other planets in conjunction with extensive ground-based monitoring at higher frequencies. A few, suitably instrumented, rockets should be available for launch on short notice to obtain ultraviolet spectra of comets on a target of opportunity basis. Large radio and radar dishes and interferometers are needed for mapping of planetary and asteroid surfaces.

To acquire the needed information, the following specific objectives have been established:

- Map the basic cloud structures and their changes on Venus, Mars, Jupiter, and Saturn.

- Measure variations, if any, in atmospheric composition and temperature of the planets Venus, Mars, Jupiter, and Saturn.

- Determine the isotopic composition of the atmospheres of the major planets.

- Obtain ultraviolet and infrared spectra of planets and bright comets.

- Measure properties of planetary surfaces and asteroids by various techniques including radio and radar.

- Map the planets for radio emissions to determine their location and characteristics, and their changes in characteristics with time.

The astronomer today not only seeks to learn and understand the stars and galaxies, such as their motions, sizes, compositions, ages, structures, and evolution, but also seeks to know the nature and behavior of the material and the fields between the stars and galaxies and their relation to the stars and galaxies. These significant factors have led to the development of the following broad objective:

3 - Determine the fundamental characteristics of interstellar and intergalactic matter and fields.

This implies the use of large highly sensitive instruments with high spatial and spectral resolution for use in making observations in all wavelength ranges, including those wavelengths accessible with existing lower resolution ground-based instruments. Wide wavelength coverage and the absence of the turbulent atmosphere are equally important for these investigations, but to fully utilize the absence of atmospheric disturbances will require better optics than those usable below the atmosphere. In addition to the high resolution spectroscopy and imagery, detailed polarization maps must be made in each wavelength region.

To acquire the information needed to achieve this objective, the following specific objectives have been established:

- Determine element abundance and physical state of the interstellar gas and its variations with location.

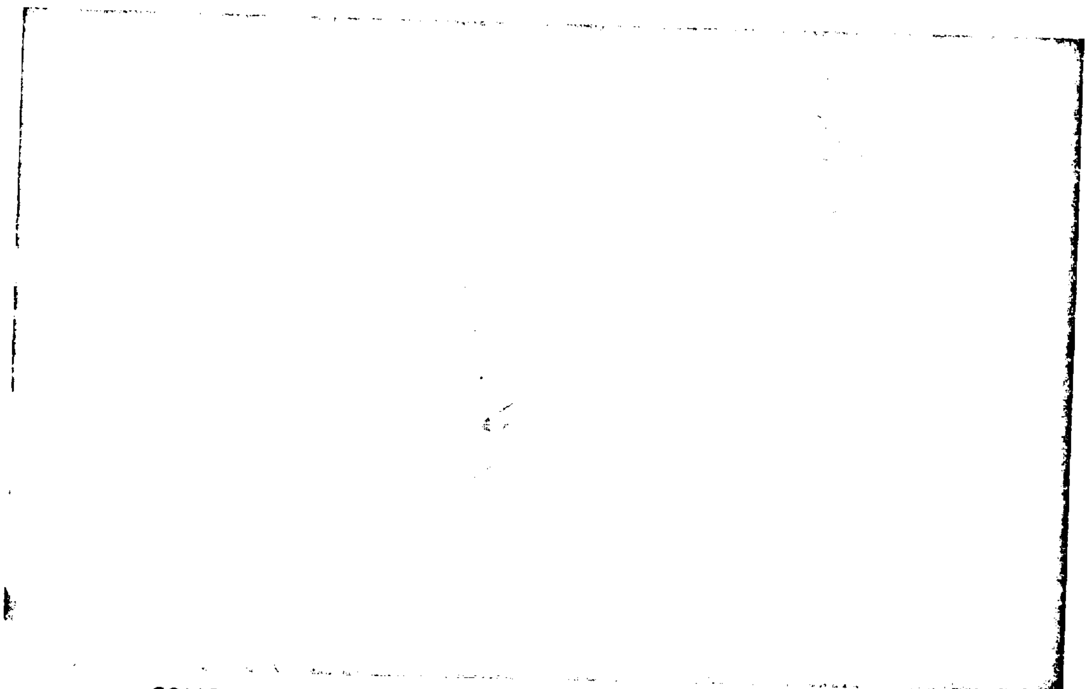
- Map the presence and distribution of infrared nodules in nebulae which may represent the early stages in the evolution of a proto star.

- Map in detail gaseous nebulae as a clue to understanding large scale turbulence shock waves and magnetic fields and an understanding of the role of these processes in the evolution of the galaxy and the individual stars.

- Obtain high resolution photographs of dust filaments, globules, and Herbig-Haro objects for clues to the process of star formation.

- Determine the total amount and wavelength dependence of interstellar extinction and polarization as a function of location in the galaxy.

- Determine the spectral distribution and spatial isotropy of the "three degree Kelvin" background radiation.



CONCEPT OF HIGH ENERGY ASTRONOMY OBSERVATORY FOR X-RAY, GAMMA RAY, AND COSMIC RAY INVESTIGATIONS

Foremost in our search for knowledge is to learn more of the physical processes in the universe, especially the changes in the matter and states of stars. But before we can have a sound understanding of how and why these changes take place, it is essential that we know their physical characteristics. An important broad objective of the program therefore becomes:

4 - Measure the emitted energy distribution of celestial objects including normal stars and galaxies, quasars, and pulsars, to improve our understanding of their physical natures.

This broad objective implies observations from space platforms in all of the regions of the electromagnetic spectrum from hard gamma rays to long-wave radio waves, as well as observations from the ground in those wavelengths accessible to ground-instruments. These observations are to be made with moderate or high spatial resolution, moderate spectral resolution, high photometric accuracy, and, for some observations, with two senses of polarization.

CURRENT SOURCES OF KNOWN X-RAY RADIATION

Steps leading to the identification of these physical characteristics are represented by the following specific objectives:

- Measure the bolometric brightnesses of normal and various types of peculiar stars.

- Determine the abundance of elemental components in stars and the extent to which these vary among normal stars.

- Obtain the energy distribution over the total wavelength range for Seyfert galaxies, radio galaxies, and quasars to determine their similarities and differences and as a clue to the physical processes occurring therein.

- Detect chromospheres and circumstellar envelopes in a number of late type stars and determine their gross physical characteristics.

- Increase our understanding of multiple stars and their interactions.

- Measure the X-ray and soft gamma ray spectra of the brightest X-ray stars to determine their atomic composition and physical characteristics.

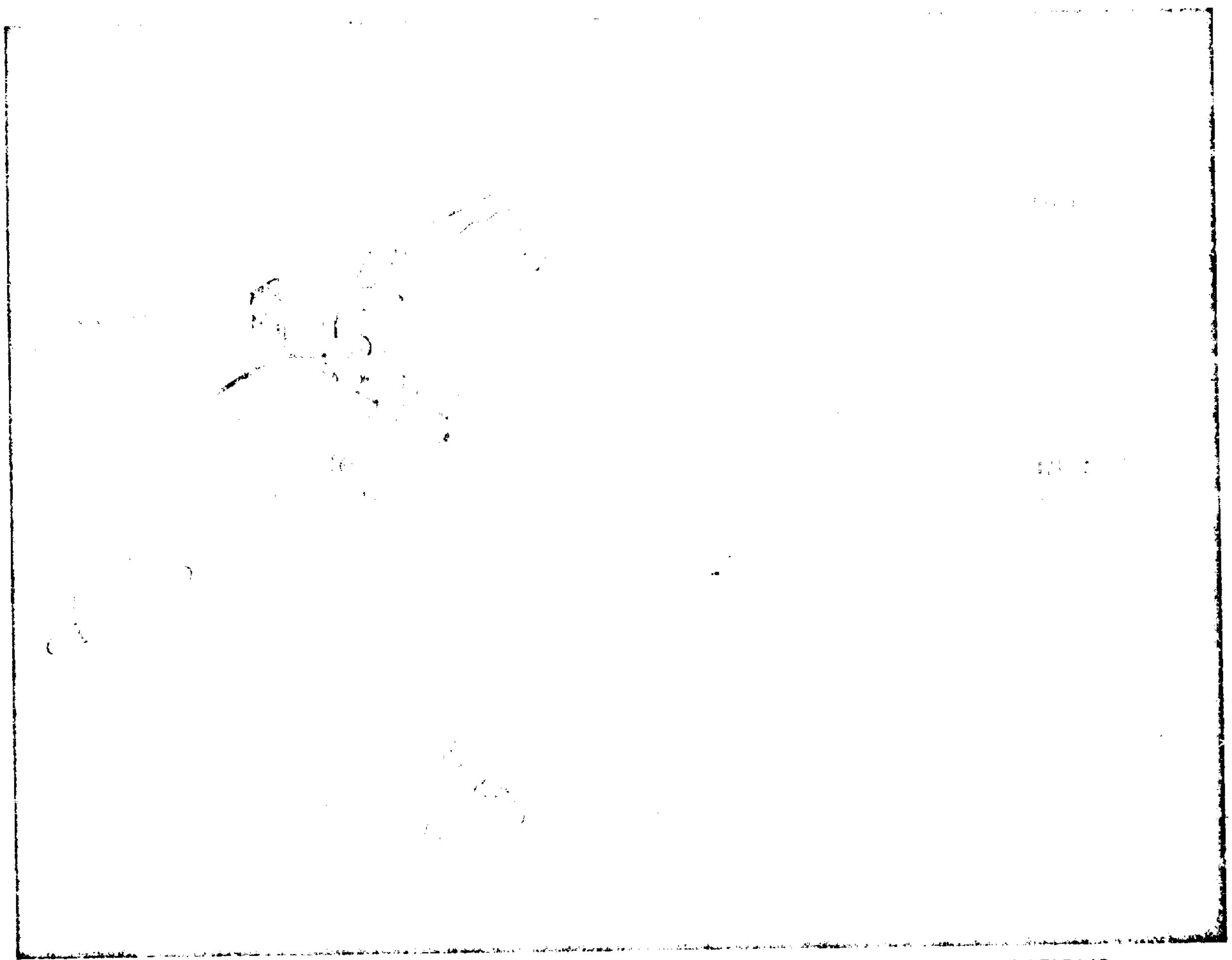
- Measure the polarization of bright X-ray sources to establish the physical process involved.

- Determine the magnetic field in non-thermal radio sources by measuring the low frequency cutoff.

The whole history of the universe is a particular area of inquiry, for by astronomical observation we are able to get the basic data with which to inquire into the amount of curvature of space and the rate of expansion of the universe. This challenge leads to the following broad objective:

5 - Determine and interpret the spatial and temporal distribution of celestial radiation sources in various regions of the electromagnetic spectrum.

This objective implies repeated observations of selected representative objects over periods of minutes, days, and years to monitor short and long term changes. These observations will normally require moderate sensitivity, wavelength, and spatial resolution. Studies of the spatial distribution of radiation will require both broad-band wide-field telescopes for background surveys, and instruments of extremely high spatial resolution and high sensitivity studies of the size and structure of very distant objects. For spatial mapping in the X- and gamma-ray regions, the next step beyond the present Explorers requires payloads of several tons because of both the paucity of photons and the physical dimensions required to obtain even moderate spatial resolution.



LARGE ASTRONOMICAL ORBITING FACILITIES CONCEIVED FOR FUTURE INVESTIGATIONS IN VARIOUS AREAS OF ASTRONOMY

The information needed to achieve this broad objective is embodied in the following specific objectives:

- Map the diffuse X- and gamma-ray background to determine the galactic or extragalactic origin.

- Determine the energy dependence of variations in the intensity of X-ray sources, pulsars, quasars, and variable galaxies.

- Determine the ultraviolet energy distribution of various types of galaxies to correct distance criteria based on galactic magnitudes for the effect of red shift.

- Obtain accurate locations for at least twenty-five X-ray stars to permit the optical identification and study of these objects.

- Determine the galactic and extragalactic distribution of X-ray stars through surveys which reach at least an order of magnitude fainter stars than those currently available with rockets.

- Determine the spatial distribution of radio emissions from the celestial sphere.

- Determine the spectral distribution and spatial isotropy of the "three degree Kelvin" background radiation.

- Measure angular diameters of remote galaxies to determine the scale and curvature of the universe.

- Measure sizes of objects such as quasars and structural detail in other galaxies.

One of the current theories about the universe states that the universe always looks the same from any point at any time. New discoveries in recent months are beginning to present arguments against this "steady state theory." The thrilling thought of discovering new phenomena that might revolutionize our picture of the universe, or of fundamental physics, leads to the broad objective:

6 - To discover phenomena not yet observed and/or not predictable on the basis of today's knowledge.

This objective implies surveys of a large number of representative areas of the sky in all wavelength ranges inaccessible to the ground, with progressively increasing sensitivity as well as improved wavelength and spatial resolution. A portion of the time, with comparatively high resolution instruments, will have to be devoted to exploratory investigations with relatively little likelihood of positive results for an individual investigation. New phenomena, when discovered, must be observed with a large number of instruments, both in space and on the ground to provide the broad wavelength and parameter coverage necessary for a physical understanding of the phenomena.

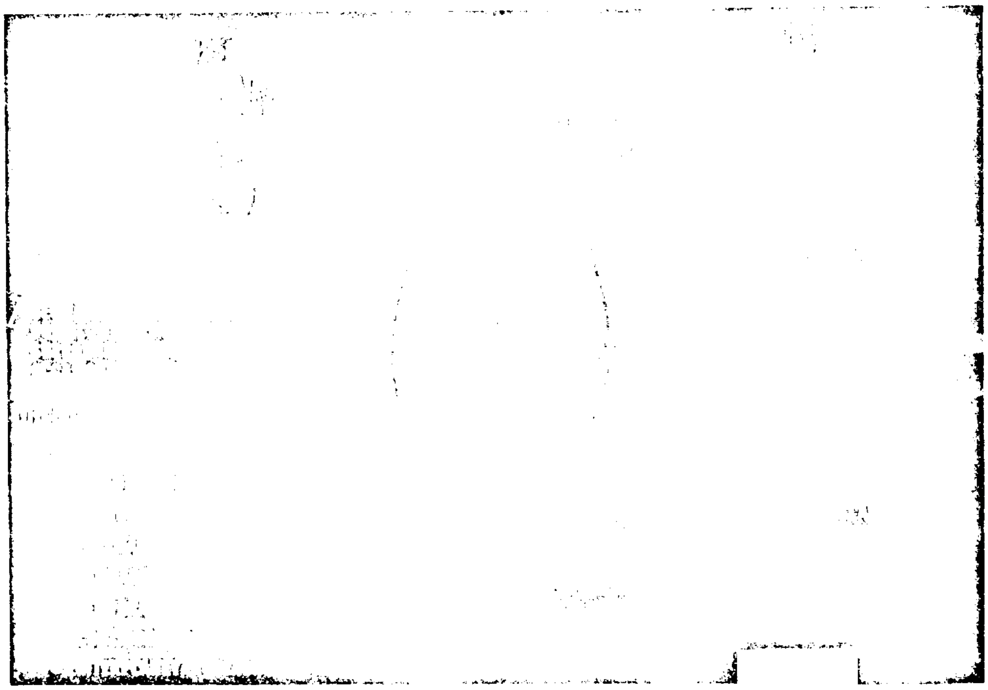
The supporting specific objective in this area is:

- Search for previously unobserved classes of celestial objects, such as planets of other stars, gamma-ray stars, proto stars, etc.

SPACE PHYSICS

Over the years, mankind has shifted the frontier of investigation from his immediate environment to the earth's upper atmosphere. With the introduction of rockets and artificial satellites, we are able to continue this shift upward into space. Thus, for the past ten years, efforts have been directed toward the exploration of the space around us, and a better understanding of the phenomena found there.

Ten years of exploratory effort have taught us how to make physical measurements in space, and have produced results that can only be described as revolutionary. As a matter of fact, many concepts as we understood them in the 1950's have required major revision. In addition, a number of totally unexpected new phenomena have been discovered whose understanding provides us with new challenges.



CHANGES IN CONCEPTS OF THE EARTH'S ENVIRONMENT THAT RESULTED FROM DISCOVERIES DURING THE FIRST DECADE OF SPACE EXPLORATION

For example, we once thought of interplanetary space as being an almost ideal vacuum containing only the familiar planets, comets, asteroids, and the Zodiacal Cloud. We now picture interplanetary space as seething with various energetic particles that the sun constantly spews forth in the form of an ionized but electrically neutral gas called the solar wind. This solar wind flows outward from the sun in great spiral paths like the flame of a 4th of July pinwheel. We once represented the earth's magnetic field as lines of diminishing strength extending without limit into space. Our current understanding is that the earth's magnetic field, which is being constantly bombarded by the solar wind, has a definite boundary and is shaped like a "doughnut and tail." The region of space occupied by this field is called the magnetosphere – a word that had not even been coined ten years ago. We have found that the earth is surrounded by a concentration of energetic particles or belts of radiation called the Van Allen radiation belts; that the upper atmosphere consists of a population of diverse particles that interact not only with each other but with solar radiation and the dense neutral atmosphere below; that the earth has a hydrogen geocorona or gaseous envelope that reaches outward thousands of miles and merges imperceptibly with the extended solar corona.

The current program extends our exploration out to regions of space not previously explored. It also continues with the observation and study of regions already explored, so that we may more completely define the processes occurring in these regions. This latter portion of the program is presently changing its character. The exploratory survey of the earth's environment, that characterized the past ten years, is being replaced with a study of the specific processes or physical mechanisms responsible for the phenomena that we have observed. These and future studies will lead to the development of a detailed quantitative understanding of our environment.

Goal

The proposed program, when viewed in the framework of broad scientific and technological efforts of the future, is another step in the direction of achieving the Space Physics goal, which is:

- To explore the space environment, to understand its nature and the physical processes that shape it, and to increase our knowledge of the fundamental laws and principles of physics.

To attain this goal various physical processes will be studied, not only in the Space Physics Program but also in other NASA programs such as Astronomy and Planetary Exploration. Within this overall activity, the Space Physics Program is concerned specifically with in situ studies of the earth's environment above 60 Km., study of interplanetary and interstellar space, and the conduct of physics and chemistry laboratory experiments that have to be carried out in space. Although the primary objective of this program is to gain basic knowledge, emphasis will be placed on those areas of activity that may form the basis for future applications or provide information needed in other areas of research.

Possible Future Accomplishments

The accomplishments to be expected from an aggressive research program may be exemplified in terms of six capabilities. These capabilities, their implications, and possible impact on mankind are briefly described in the discussion that follows.

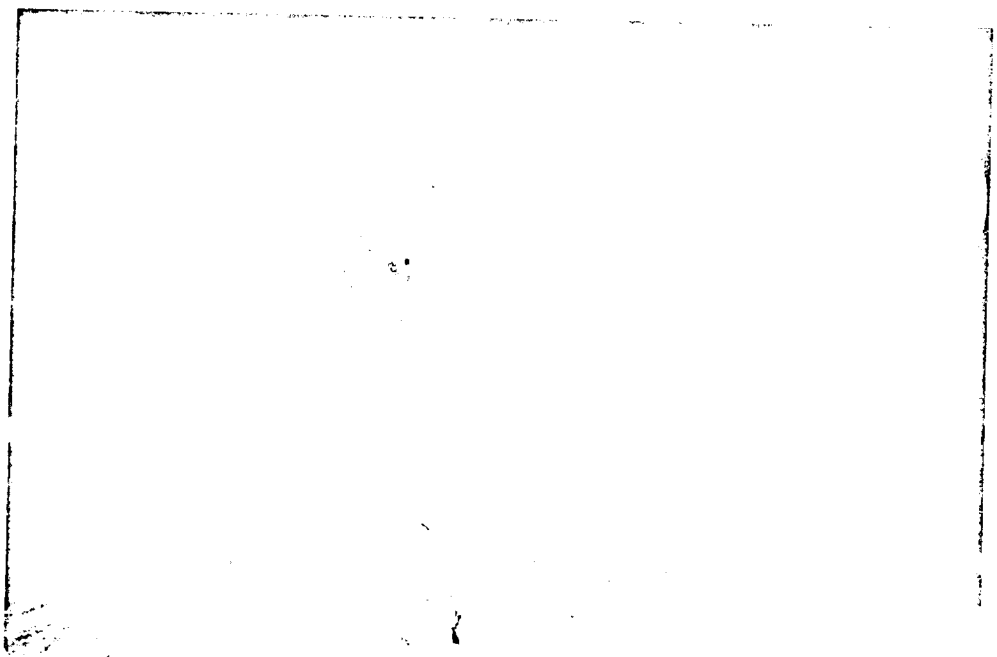
The first of these possible accomplishments is:

- To be capable of assessing the degree to which man can predict, modify and control the earth's environment.

The sun exerts a profound effect on the environment of the earth, controlling both the meteorological and space climates. An important goal of the Space Physics Program is to understand the processes by which this control is brought about, with a view toward predicting and, possibly, modifying their action. An understanding of the major features and processes of sun-earth relations may lead us to the identification of trigger mechanisms that could be used to control the earth's environment for the benefit of mankind. The results from the proposed basic research should place this country in a position to assess the practicability, desirability, and dangers inherent in such modifications and permit decisions about the desirability of an applications program in environment control. Practical objectives might include modification of global weather patterns; control of artificially produced radiation in space such as that produced by the 1962 nuclear tests; or making the natural environment more suitable for space operations.

The second possible future accomplishment is:

- To know the value of continuously monitoring the conditions in space (which we might call a "space weather" patrol) and develop techniques for implementing such a monitoring system.



EXPLORER SATELLITES FOR INVESTIGATION OF EARTH'S UPPER ATMOSPHERE

Changes in our immediate environment, such as atmospheric weather and disruption of ionospheric radio communications, are to a larger or smaller degree responsive to changes in the outer space environment. A better understanding of these relations should permit us to determine whether it is of economic value to monitor or even forecast changes in outer space. Spacecraft systems and instruments to be developed for this assessment are expected also to lead to the type of automated, long-life spacecraft needed for an operational system.

Another possible accomplishment that we foresee by the mid-1980's is:

- To have an understanding of the laws and processes that govern the behavior of ionized matter in the solar system.

The sun's atmosphere, or heliosphere, expands outward into space continuously to envelop the earth and other planets. This outward expansion produces a solar wind. The sun's outer corona appears to be a fully ionized but electrically neutral gas, which is referred to as plasma. Plasmas constitute what has sometimes been called a "fourth state of matter." An understanding of the physics of plasmas is likely to yield benefits in the form of new devices for power conversion, and will provide the basis for interpreting some of the phenomena observed by the Planetary and Astronomy programs. Dense plasmas play an important role in stars; tenuous plasmas fill the universe; and plasma interactions, which are as yet not understood, are thought to account for the energy radiated by pulsars, by quasars, and by the radio sources on Jupiter. Plasmas are intrinsic in the structure of comets. The ionosphere and magnetosphere, the solar wind as it travels away from the sun, and the interaction of the solar wind with comet tails and the interstellar medium provide us with a unique laboratory for studying fundamental processes in collisionless plasmas. The processes to be studied govern the transfer of energy between magnetic fields, energetic particles, and electromagnetic radiation; processes that on a stellar scale account for the release of tremendous amounts of energy.

An accomplishment that is important to our future manned exploration of Mars is:

- To know the natural hazards of manned interplanetary travel.

Given man's natural curiosity and desire to meet external challenges, it is an inescapable conclusion that he will eventually explore the solar system. However, once on his way to another planet, he will no longer be able to return rapidly to the protective environment of the earth. Our present awareness of natural hazards is limited to radiation and meteoroids. In neither case are we able to assess the full significance of their hazards. Acquiring detailed knowledge of the environment will permit man to design spacecraft so that he may successfully operate in interplanetary space with a minimum of hazard.

A further accomplishment that may be possible to achieve by the 1980's is:

- To have a basic understanding of the nature of gravitational forces, gravitational waves, and general relativity.

The gravitational force is an enigma; it is the weakest force in nature, on the order of 10^{-40} to 10^{-38} times nuclear and electromagnetic forces, yet it harnesses as much energy in the universe as the others. Even though it is the first of the universal forces to be identified, (Newton) we have as yet learned little about its detailed properties because its weakness makes it almost inaccessible to laboratory studies. By the use of space, we can study accurately the interaction between light and gravity, search for gravitational waves, and study relativistic effects on planetary orbits and on the precession of gyroscopes in order to test Einstein's general theory and establish necessary refinements. Potential practical applications of this knowledge are far in the future; it will, however, be an essential ingredient in the interpretation of astronomical observations and in the formulation of any theory about the evolution of the universe.

The final future accomplishment that we foresee is:

- To have proven the value of a physics laboratory in space and to have conducted exploratory investigations.

A laboratory in space offers unique features not attainable on earth, such as an effectively gravity-free environment, absence of wall effects, and the natural availability of particles h much higher energies than can be produced artificially. Since this is a new area of endeavor, we have not yet developed specific investigations or experiments to be conducted. Major surprises are anticipated in such a new program, and the initial objective will be to prove the scientific value of the program and its potential for practical applications.

1980 to 1985, it is expected that the high energy physics program will have provided us with an understanding of the most energetic processes in nature -- acceleration of particles to millions of billions of electron volts and elementary-particle interactions at those energies. Results anticipated in the physics and chemistry laboratory will lead to new insights into the nature of the solid state and show the way to new processes and techniques usable on the ground. Other results from this laboratory may find application for extended space activity such as a lunar base or manned flights to the planets.

ese six examples are illustrative of the potential accomplishments to be expected from a Space ysics Program. The direct results of the proposed research, however, will be scientific knowlge; and it is through this new basic scientific knowledge that we can further develop our chnology. These technology advances will, in turn, lead to new techniques and new truments, which very often speed up our work in basic science and lead to ways of uncover- yet further secrets of nature. The long-term contributions to scientific knowledge expected m this program are expressed in the terms of broad objectives. It is the nature of scientific earch, however, that its outcome cannot be predicted accurately and, as a consequence, objectives are open-ended rather than definitive.

jectives

previously mentioned, our exploration of the earth's space environment has revealed a range entirely unexpected phenomena, such as regions of trapped radiation and a definite boundary the earth's atmosphere and magnetic field. Our studies of space have shown that many of se phenomena result from complex, large scale interactions of solar energy with the earth's osphere and magnetic field, but the detailed mechanisms are not understood. Now we aim understand the physical processes and interactions that shape our environment. For instance, are searching for the mechanism by which energy is transferred from the solar wind into the gnetosphere, processes by which particles are energized, and the balance between various otochemical reactions in the upper atmosphere. This leads us then to the first of five broad ectives:

I - Obtain a detailed understanding of the physical interactions and dynamic processes which control the earth's space environment.

achieve this objective requires that we continue to observe solar cosmic rays, electric ds, the solar wind, and fluctuations and interaction of the solar wind with the earth's gnetic field. From these observations, we will be able to determine how the earth's ck front, magnetic boundary, and magnetic tail are formed; how the solar wind drives gnetospheric processes such as electrical currents, auroral activity, and energetic pped radiation. We will also observe the bow shock, magnetopause, and magnetotail determine how they vary with time and space. Simultaneous observations will be required he solar radiation, electric fields, the motion and diffusion of the earth's atmosphere and osphere; and global distribution of the composition, temperature, density, chemical nges in the atmosphere, and their variations with time, position, season, solar cycle and earth's magnetic activity. Such measurements will lead to an understanding of how solar activity affects the earth's atmosphere and ionsphere. The information described above will lead, in the latter part of the next decade, to experiments with artificial environmental perturbations to discover and understand natural trigger mechanisms in the environment. The knowledge to be gained from this broad objective is expected to provide tangible benefits in forecasting environmental changes which may affect weather, communications, and manned space travel. Such knowledge may ultimately provide the means to exert some control over our environment.

Based on the type of information that is needed to achieve the above objective, the following supporting specific objectives and sequence of accomplishment have been established.

Initial objectives:

- Determine the dynamic plasma properties of the earth's magnetosphere, such as mechanisms for transferring energy from the solar wind into the magnetosphere and the sources of energetic particles in the magnetosphere.

- Determine the photochemistry of the earth's atmosphere and of the solar radiation and physical forces responsible for the structure and behavior of the neutral atmosphere and ionsphere at altitudes of 60 to 300 Km.

Intermediate objectives:

- Complete the investigations leading to a full determination of the processes related to our environment, such as studies of the three-dimensional properties of magnetospheric regions, and investigation of the termination of the geomagnetotail.

- Perform initial studies of the reaction of the environment to minor perturbations.

Long-range objectives:

- Search for trigger mechanisms that control the earth's environment, including:

  - Change of heat balance of the upper atmosphere to study coupling between the upper and lower atmospheres.

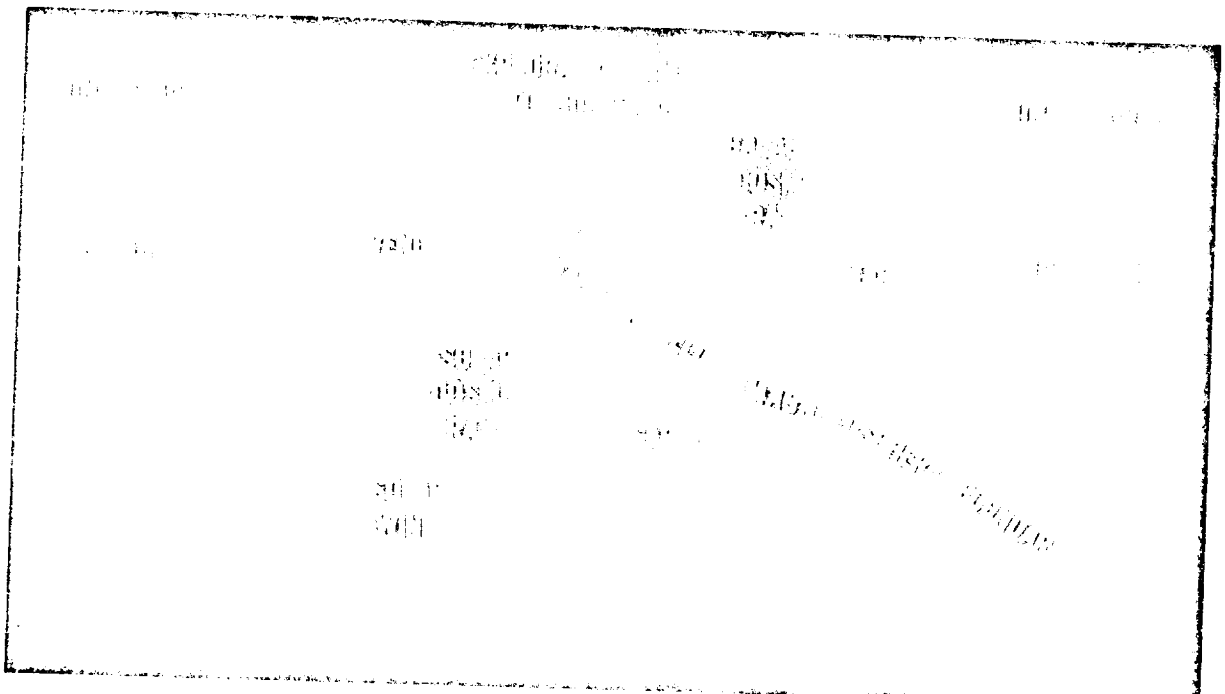
  - Change of natural or induced radiation environment affecting operation in space.

- Study long-term changes in our environment such as geomagnetism, Van Allen belts, and solar radiation effects of the upper atmosphere.

Exploration and discovery have, throughout man's history, had a profound influence on his existence in ways which could not be predicted at the time. Figuratively speaking, our initial exploration of space has been generally limited to our backyard. As yet we know very little about vast regions far out from earth, both toward and away from the sun. Exploration near to the sun will provide data pertinent to our nearest star and source of life-sustaining energy. Far from the sun (100 AU), we may investigate the particles and radiations from the universe, free from the filtering influence of solar wind and solar magnetic field. The second broad objective expresses this aspiration.

2 - Explore in situ the region of space extending from the sun out to interstellar space in order to increase our understanding of the nature and evolution of the solar system and the universe.

So far, our investigations have been limited to relatively short distances from the earth and have been confined to the plane containing the earth, the sun, and the planets, known as the ecliptic plane. It is important that we investigate the space environment outside the plane of the ecliptic for comparison with the investigation already made in the ecliptic plane. It will be important also to undertake very detailed observations of the interplanetary medium that can only be performed near the earth because of telemetry limitations. To accomplish these investigations may well require the use of advanced technology in electric-power generation, thermal control, and high impulse propulsion.



EXPLORED AND UNEXPLORED AREAS OF THE EARTH'S INTERPLANETARY ENVIRONMENT

eps to be taken in obtaining this information lead to the following specific objectives:

the near term:

- Explore in the plane of the ecliptic from 0.3 to 5 AU from the sun.

- Study the character of the solar wind and cometary phenomena, the distribution and flux of dust and asteroidal matter, and the gradient of cosmic rays.

Beyond the near term:

- Explore beyond 5 AU, move out of the plane of the ecliptic, and approach the sun to less than 0.3 AU.

- Determine properties of the solar wind, the gradient of cosmic rays, and distribution and composition of cosmic dust to at least 10 AU in and out of the plane of the ecliptic and to within 0.1 AU of the sun.

In the longer term:

- Explore the boundary of the heliosphere both within the ecliptic and at high solar latitudes and study long-term changes in the solar atmosphere at 0.05 AU.

Space affords a unique environment for the performance of experiments not feasible on earth, such as laboratory-class experiments performed aboard a space platform, studies using plasma outside the spacecraft, and gravity-relativity experiments that require large changes in gravitational potential. This leads naturally to the following broad objective:

3 - Exploit the unique characteristics of space to conduct physics experiments not feasible on earth.

Implied in this objective is the requirement for a space platform that would permit the conduct of experiments in an environment effectively free of gravitational forces, enabling basic problems in crystal and particle growth, liquid transport, and temperature effects to be investigated. Large detectors will be required to permit the study of extra-high energy cosmic ray particles that cannot be observed directly on earth. In addition, such detectors will permit the observation of elementary-particle interactions with target materials at energies much higher than those available with accelerators on earth. Even a few well-recorded interactions at these energies could profoundly affect our understanding of the basic nature of matter. The injection of chemicals, particles, or electromagnetic energy into a space environment can introduce plasma perturbations under controlled conditions. In this way, we can use the natural environment to study plasma physics problems which are unsuitable for study with ground facilities.

Most of these experiments fit naturally into a manned space station if one becomes available in the middle of the decade. If not, some could be accomplished with automated spacecraft. The gravity-relativity experiments will require, in general, special automated missions. Investigations of the propagation of light in a gravity field relies on the development of a clock with an accuracy of one part in 10^{13}. Similarly, a measurement of the relativistic precession of a gyroscope depends on the development of an ultrastable gyroscope that has progressed to the point where a test in space is required.

he supporting specific objectives in this area are:

s a first step:

- Determine gravitational effects through accurate measurement of the red shift and the gravitational quadrupole moment of the sun.
- Determine the character of galactic cosmic rays (10^{10} to 10^{14} ev) and perform initial interactions experiments at these energies.
- Define experiments when the combined or individual effects of vacuum and zero gravity are important, such as: solid state physics, colloidal chemistry, flame chemistry, and heat transfer.

As we progress in our understanding of how to use space:

- Perform experiments with relativistic gyroscopes.
- Attempt to detect gravitational waves.
- Study elementary particle physics using the natural high energy (10^{11} to 10^{15} ev) cosmic ray beam.
- Conduct studies in physics and chemistry in the space station laboratory.
- Perform plasma physics experiments in the surrounding medium.

THE USE OF SPACE TO CONDUCT GYRO RELATIVITY EXPERIMENT

The information needed to attain the above objectives will have applications well beyond those objectives. We are interested in practical applications to other parts of the space program and scientific applications in support of investigations in other disciplines. Our knowledge of the earth environment has enabled us to use magnetic, gravity and solar pressure stabilized orientation systems; to use the earth's infrared radiation, the sun's illumination, and the stars for attitude control and navigation; to convert solar radiation into electric power; and to make use of the sun's energy, the earth's albedo and cold space for thermal control. Our knowledge must be extended further to include details of environmental parameters in space in order to minimize the hazards of intense radiation, micrometeoroidal matter and other potential dangers. For example, we are aware that satellite stabilization and orbital lifetimes at low altitudes are critically dependent on atmospheric drag; electronic systems are damaged by intense particle radiation; communications are affected by conditions within the ionosphere and, at some frequencies, are masked by natural background noise. Hazards to manned operations near earth or in interplanetary space, particularly in as yet unexplored regions, need to be defined as a function of position, and how they vary with time if safe and successful manned interplanetary travel is contemplated. An important broad objective of the program therefore becomes:

4 - Provide a model of the space environment for use in design and to assess the hazards to men and machines.

The missions to be undertaken for investigating the geophysical environment and interplanetary space will provide the basic information needed for this objective. Extensive compilations of pertinent information will be required and "best values" will have to be derived from measurements that are not always in complete agreement.

The following broad objective defines the scientific application to other disciplines:

5 - Use our understanding of the space environment to aid in the interpretation of data from the environments of other planets and other parts of the universe.

Knowledge of our planet, its magnetic field, the chemistry of its atmosphere, and the surrounding tenuous plasma, including response to external influences, bears on studies of other planetary objects and on processes believed to occur on stellar and galactic scales. Measurements of cosmic rays and interplanetary characteristics provide indirect but revealing information about solar and galactic processes. Since the earth's environment shows important similarities to and differences from the environments of other planets, our knowledge of this environment provides a means for interpreting scarce observations of the other planets and for testing the general applicability of theories. Dense plasmas play an important role in stars, and plasma interactions are thought to account for the energy radiated by pulsars, by quasars, and by radio sources on Jupiter.

The required information will be obtained by detailed in-depth analysis of pertinent data resulting from investigations performed to accomplish the first three broad objectives stated above. Where necessary, mission profiles or instrumentation may be adjusted on the basis of requirements posed by this objective.

lowing specific objectives, that will lead to a model of the space environment and to ation that will aid us in interpreting data from other disciplines, support both the 4th broad objectives:

Prepare further handbooks of important characteristics of the geophysical environment such as density in the upper atmosphere and its variations, radiation hazards, and the geomagnetic field.

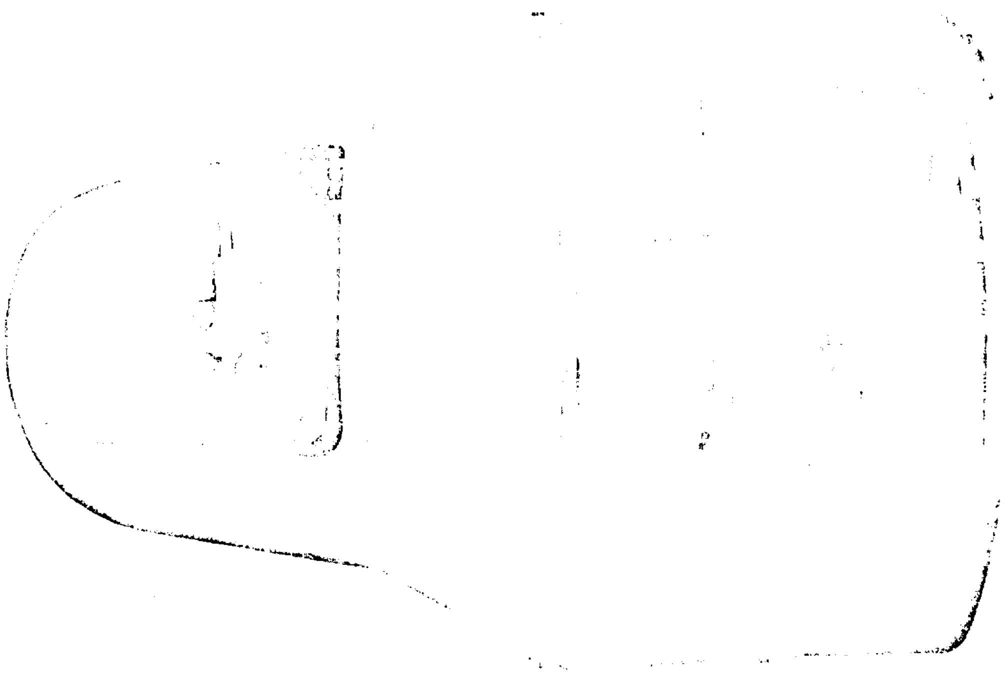
Maintain an easily accessible library providing a visual data presentation and a catalog of available space data; containing photographs, summary plots of various measurements such as particle fluxes, ion densities, or magnetic field fluctuations, and complete records of reduced data.

Make theoretical studies of the earth as a planet and use the resulting models to interpret the relatively scarce data from direct planetary observations.

1975, archiving of data from various space missions will assume increasing importance. it time, techniques should be available for compact and permanent storage of exceedingly volumes of data. Similarly, computer access to the data should be rapid and standardized. endency will be towards relatively few super-computer centers with remote access to the iter available at the institution of the investigator.

e at the beginning of a biological revolution which will surely gain momentum over the
lecade. In these developments, Space Biology will play a special role.

nt-day biology is looking at the nature of life in broader terms than ever before, raising
ons about the universal conditions of life, its origin, evolution, and its ultimate limits.
Biology provides opportunities for experiments in environments that have never before been
able to the biologist. As man and other earth organisms enter extraterrestrial space, they
e removed from the gravitational forces under which they have evolved, and can be
ded from those factors which, on earth, act as timesetters for the periodic processes and
ms that are characteristic of life.



BIOSATELLITE SPACECRAFT

Space Biology flight research program, backed up by ground-based studies, has centered on
Biosatellite, a recoverable spacecraft especially designed for biological experiments. The
t flight mission gathered data on the effects of exposure to weightlessness and radiation--both
arately and concurrently--on the metabolism, growth, and reproduction of relatively simple
nt and animal tissues. The second Biosatellite mission, launched in June 1969 and using an
borately instrumented monkey as the experimental subject, provided data for eight days on
performance and reactions of the central nervous system and the cardiovascular, metabolic
d circulatory systems during weightless conditions. Detailed analysis of the data from these
ghts is continuing.

als

ese activities, in space and in laboratories on earth, support the central aims of Space Biology
expressed in the following program goals:

- Through research in space, to bring a new dimension to our study of life, thus contributing to the development of understanding in biology.

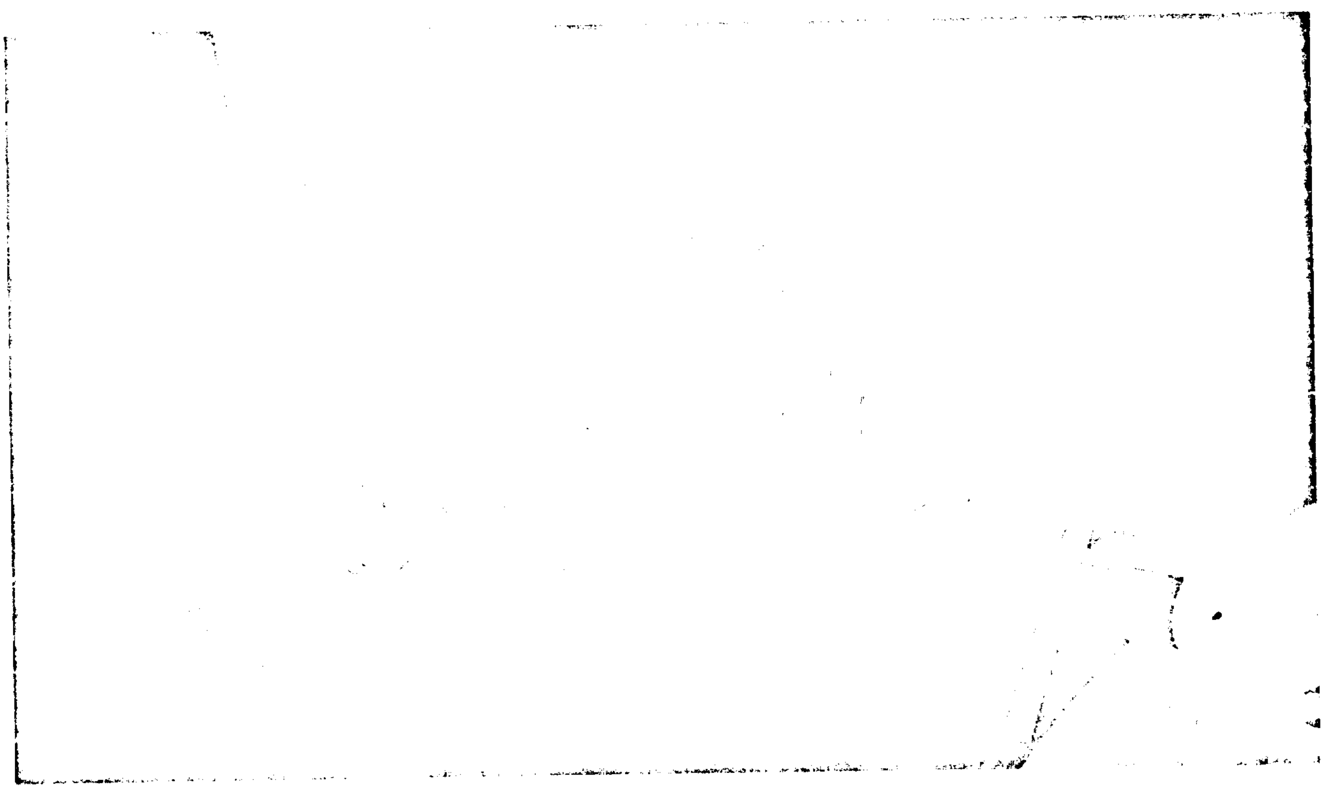
- To enhance, by virtue of this fuller understanding, the powers of prediction and control in the applied fields of medicine, agriculture, and public health, and in environmental management.

Space Biology thus extends the scope of environmental biology, by introducing organisms into a totally new environment, and in so doing, providing a new level of generality.

Possible Future Achievements

It is reasonable to anticipate that, through the vigorous pursuit of its goals, the Space Biology Program will make unique and substantial contributions of great value to mankind. Perhaps the most significant future achievement to which the biological community may aspire during the next two decades, and to which space biology will contribute, is:

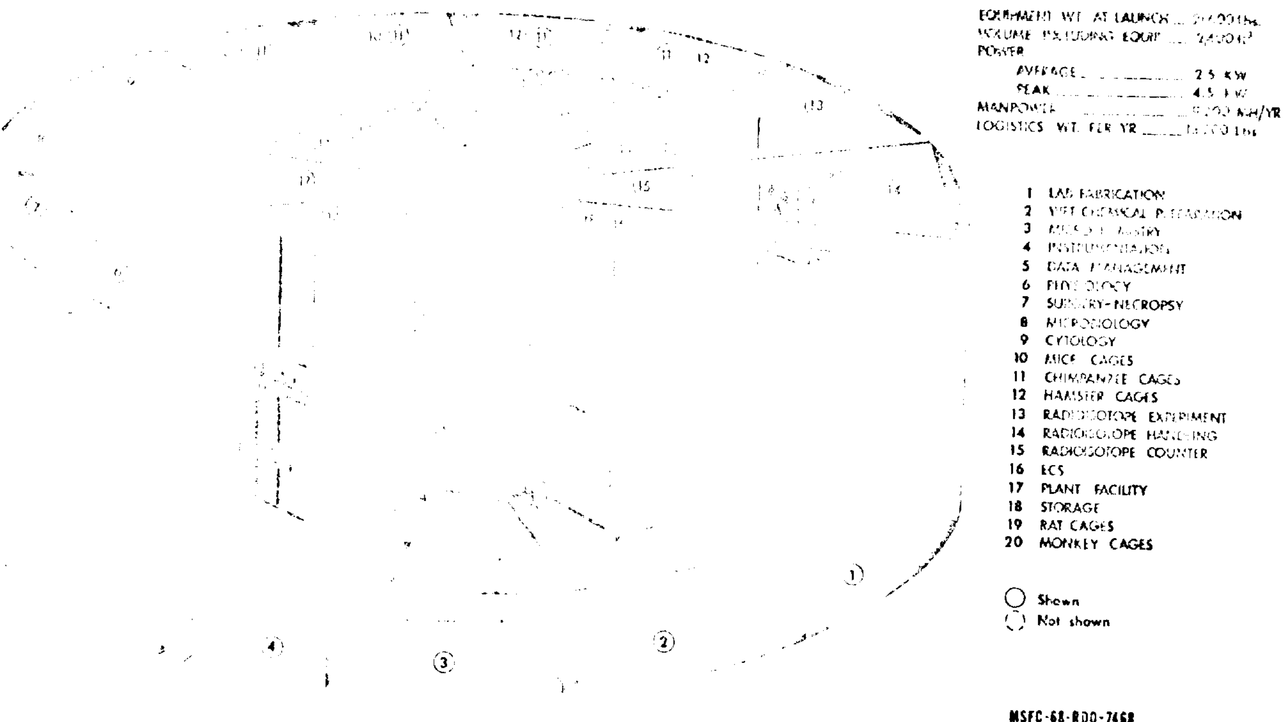
- The development of coherent and unifying theory in biology.



CONCEPT OF MANNED MODULE FOR PLANT SPECIMEN EXPERIMENT IN EARTH ORBIT

The most significant unifying theory in biology developed to date is Darwin's theory of evolution. It -- together with the cell theory, the germ theory of disease, and the theoretical work in genetics -- has served as the broad framework for modern biological and medical research. This research, in turn, has revolutionized human life in a few generations. Marked improvements in disease control, food production, and human life expectancy have occurred through empirically developed knowledge from experimental programs grounded in these theoretical concepts.

win himself endeavored to incorporate gravitational considerations into biological theory the simulation of weightlessness, and lamented the fact that it would never be possible to nove organisms from gravity. Thus, he felt that its influence could never be understood.



CONCEPTUAL ARRANGEMENT OF BIOLOGY LABORATORY IN A SPACE STATION

ce the day of the early biological theorists, theory in physical science and knowledge of chemical processes have made major contributions to biology. Chemical activities in the tube, however, differ greatly from the chemistry that occurs in the highly organized cture of cells. Thus, the further development of generalizations that will be of predictive ue in molecular biology require an understanding of the role of both cellular architecture gravitational forces in living processes.

e-setting factors, such as the solar day and the lunar month, can be uniquely controlled emoving organisms from earth. Similarly, the gravitational force can be varied or ctively eliminated. The availability of these new conditions for experimentation allows study the influence of time and gravity on multiple functions of single cells, and on ular interactions in a wide spectrum of species. These experiments range from basic ies on the growth of plants, to investigations into the subtle effects of altered gravity ls and modified time cues on the orientation and long-term well-being of higher animals. in this sphere of research that space biology can make its most significant contributions.

fundamental approach of Space Biology to the study of the essential nature of life will be rtant in several ways. Not only will it search out the limits within which life can exist on e flights, other planets, or earth, but it should also lead logically to the design of optimum ronments which will protect man or cure him from disease. It could lead to expansion of able regions for the expanding human population. As a minimum, it will provide the of insight required for better overall management of man's habitat on earth.

An important related benefit accrues from the Space Biology Program by virtue of the fact that most of the experiments present special challenges in bioengineering. Often, they require entirely novel forms of technology. This has stimulated cooperation among biologists, medical specialists and engineers, changing their outlook and forcing them to provide new types of equipment, ranging from special life-support systems to unusual telemetry devices. Research and development in space biology have already provided new biological applications and technological discoveries of value to medicine, public health, and agriculture. These applications are the natural consequences of the rapid advances in this fruitful field.

All of these prospective advances come at a time when the need for a more profound understanding of life processes is especially urgent. This urgency is seen in the current national and world preoccupation with such biologic problems as a dwindling food supply, over-population, disease, and the pollution of land, air and water. These problems all entail a significant biological element and space biology may enter decisively into their solution.

The discoveries which can be expected either directly or indirectly from these endeavors thus have the potential of radically transforming our lives and our environment for the betterment of man.

Objectives

Three broad objectives, each concerned with certain aspects of the program goals, and each embracing several specific near-term objectives, have been selected to serve as the implementing focus for the Space Biology Program. The first of these broad objectives is:

I - To understand the role of gravity in life processes and the capability of living organisms to adapt to gravitational changes.

Until we began conducting experiments in space, it was impossible to determine the fundamental role of gravity in life processes. This was because a zero gravity environment could be simulated only briefly on the earth. Recent evidence from biological experiments in space indicates that weightlessness: (a) may lead to profound disturbances in cell division and chromosome integrity, resulting in significant abnormalities; (b) increases the damage which would otherwise be suffered from a given radiation exposure; and (c) produces significant alterations at the organ-system level, especially in musculoskeletal and cardiovascular functions. The determination of whether gravity has a significant role in cell division is crucial to our understanding of tissue growth and differentiation. Application of this knowledge of weightlessness to problems of man in space and to areas of medicine such as wound healing and cancer therapy, is beginning.

Within the context of this first broad objective, a group of supporting specific objectives has been identified as representing planned near-term accomplishments:

- Determine the effects of gravity on maintaining normal organization and function in living cells.

- Determine the gravity sensors of plants, the sensory thresholds for gravity, and the role of gravity in growth, development, physiology, and behavior of organisms.

• Understand the effects on the functional mechanisms in organisms occasioned by changes in levels of gravity.

cond broad objective of the Space Biology Program is a companion of the first; its vement will provide additional "missing links" which will lead us closer to an ability elop a useful body of theory of life processes:

To understand the role of time in biology, including the effects of time-varying environmental parameters on biological rhythms and aging.

ally, all life processes are timed, and all timing external to the organism is set, ultimately, smic events. Living organisms universally exhibit rhythms of varying periods, many of correspond in frequency to solar day, lunar month, annual, and other cycles. Endogenous akers or "intrinsic clocks" in organisms are phased to environmental cycles. These bio-l rhythms are essential to normal function. When organisms are isolated from cyclic cues, s daily light-dark cycles, their rhythms will "free run" at frequencies near normal.

er to understand this phenomenon, it is necessary to remove the organisms from the geo-cal environment and observe the stability of the rhythms, both "free running" and with ally imposed cyclic cues. Since the earth's geophysical environment is affected in a ignificant way by its own motion and position relative to other celestial bodies, experi- must be carried out in earth orbit, and away from both the earth and the moon, as in around the sun. Since some rhythmicities, such as tidal periods, are associated with the ational fields of two or more bodies, it will be necessary to conduct biorhythm studies weightlessness and under artifically-induced gravity.

llowing specific objectives have been established in support of the second broad ive:

- Determine the influence of earth and lunar environmental periodicities in inducing and maintaining rhythms in living organisms.
- Determine the role of biological rhythms in maintaining normal organization and life, and the contributions of innate and environmental factors to the rhythmic mechanisms.
- Determine how biochemical and physical reactions that control growth, maturation, and senescence are timed at the molecular level.
- Determine the interaction of time-dependent phenomena with gravity.

the first two broad objectives are concerned with gaining certain basic scientific edge, the third broad objective looks toward the applications of such knowledge:

- To determine the potential applications and develop the techniques to utilize new biological understanding, together with space technology to advance biology, medicine, agriculture, and space exploration.

The alteration of biological processes by manipulation of the environment has great potential for application to problems susceptible to biological solution. The time of application of a therapeutic treatment relative to the phase of a particular biorhythm, or various combinations of heat and cold coupled with medication are valuable techniques for promoting beneficial results in pest control, plant and animal husbandry, and the treatment of disease. Further, the ability of organisms to modify the environment so that is is more favorable for life is well recognized. Examples include the formation and enrichment of soils from rocks by lower plants and bacteria, and the production of our present 20 percent oxygen environment by plants. Selected organisms may exist or be produced to enhance human habitability on other planets where adverse conditions now exist.

The use of space satellites and developments in telemetry offer new capabilities for the scientific study of biology on the earth's surface. The Nimbus satellite has already made it possible to track animals in remote locations. The potential future use of satellites includes tracking economically important species of fish and other food source animals which will improve the world's food supply and allow better scientific management of plant and animal food sources, environmental resources, and control of the spread of disease.

The following specific objectives are representative of those around which space biology projects may be formulated in support of the third broad objective:

- Understand the mechanisms of and develop techniques which use zero or variable gravity to produce and correct abnormalities and to modify functional mechanisms in organisms.

- Develop the use of space systems for tracking animals and studying animal orientation, navigation, and migration.

- Utilize the experimental techniques and capabilities developed in the program to shorten the leadtime in solution of problems in biology and medicine.

- Explore the potential uses of earth organisms to enhance human habitability in space flight and in the environments of planetary or lunar surfaces.

E SURVEYS

Surveys encompasses NASA's ac s in Earth Physics (including satellite geodesy), orology, and Earth Resources Sur . The integrating factor among these three program is the focus upon understanding a predicting the environment of man on earth through e of observation systems in space that work in conjunction with ground-based receiving, itation, and measurement systems. Currently, programs are being carried out in the separate areas without a major effort to integrate them at the systems level, either in ace or ground segments. As technology and experience mature, however, it is likely nique disciplinary functions will be handled not by dedicated hardware systems but by alized ones.

ey principle underlying the Earth Surveys effort is that of eventual useful application nan needs of the scientific knowledge and operating systems developed in pursuit of the m goal. In summary form, this goal can be stated as follows:

o develop the aerospace technology and its application to the observation of he earth and its environment for:

- The definition of the earth's gravitational field, geometry, surface characteristics, and dynamic body properties.
- The understanding of the physics of the atmosphere, the prediction of weather, and the establishment of a basis for weather modification and climate control.
- The responsible management of the earth's resources and the human environment.

le Future Achievements

king toward the goal set out above with an aggressive investment of human, financial, anagement resources, it is believed that within the next fifteen years the Nation could

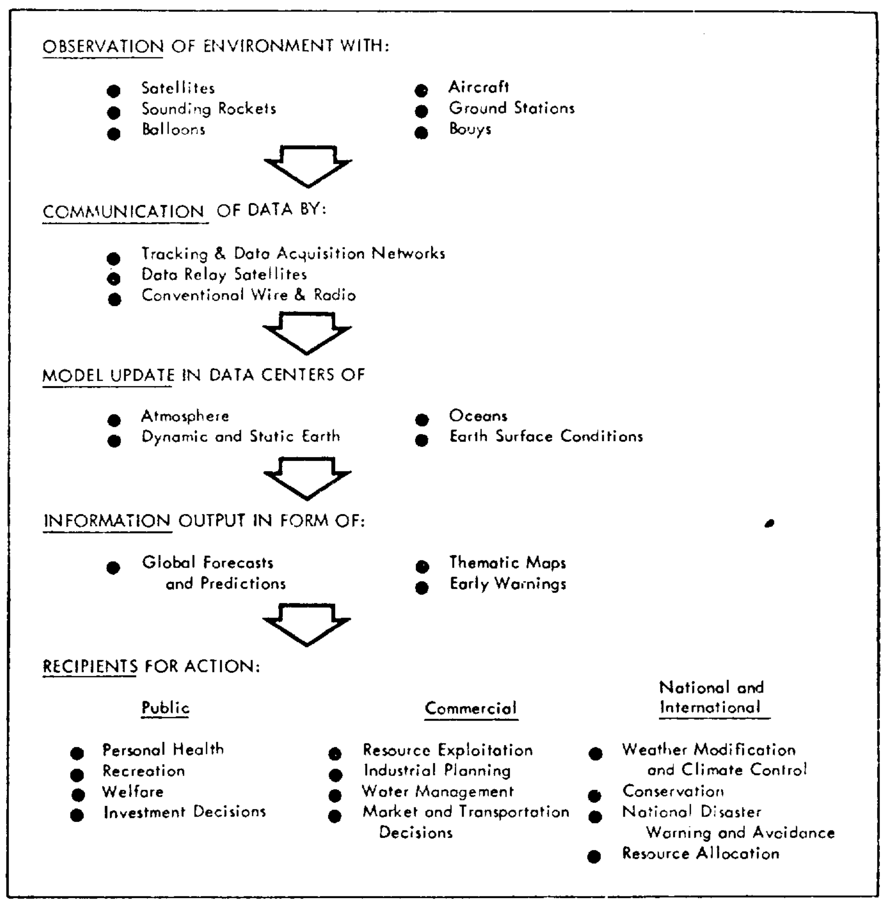
- A global observation capability to continuously acquire information on the conditions of the land, the oceans, and the atmosphere.
- A sufficient understanding of the environment to develop comprehensive models of the earth as a body, the conditions of its surface, the oceans, and the atmosphere.
- An ability to use these models and the continuing observational data to predict resource and environmental conditions accurately and, therefore, to be of use in the making of individual, group, national and international decisions related to resources and environment.

- A level of experimental background and experience sufficient to permit weather modification, climate control, and natural resource management on at least a hemispheric scale.

The interactions of man with his environment, including earth resources, are creating increasingly severe pressures both on man himself and on the ability of the earth's environment and resources to support him. More information about the environment, about the impact it has on man's activities and the reciprocal effects of those activities, has become a major need. The problems of an ever-decreasing supply of material resources, potable water, food, energy sources, and fresh air are being compounded by population increases and the demands of a technologically maturing world society. The quality of the environment is suffering, and man lacks the informational basis for decisions concerning the conservation, modification, or exploitation of the resources upon which he depends for life.

Space technology applied within the context of a total system can provide the means for attacking this problem. If sufficient effort is applied, the next 10 to 15 years will see the emergence of an integrated capability to gather information on a global scale about the resources and environment, to communicate this information rapidly and accurately to computer storage, and to utilize the information to update interrelated physical models of the earth and its environment. These computer-implemented earth science models are the key to accurate prediction of resource and environmental conditions and to the understanding of the effects on those conditions that man's activities may have.

Given a meaningful level of predictability, man can act upon, react to, or interact with his environment in his own best present and future interests. The technologies for observation, modelling, and data transfer are in hand or under development; the future achievements he can project are the integration of hardware, software, and communications into an integrated capability that can be termed an environmental management system.



ENVIRONMENTAL MANAGEMENT SYSTEM

in this direction requires coordinated effort in all the four categories noted earlier: ation systems, scientific understanding and modelling, prediction, and environmental ment decision-making based on these capabilities. In each of these categories and each of the disciplines, there are a number of achievements that are valuable in lves.

Observation. A complete system for global observation of land, sea, and atmosphere yet in being, but the space segment of such a system has been demonstrated in ology. The combination of the operational ESSA satellites with the experimental us-class satellites already provides the first step toward a global system. For weather ation, it is felt that the technique is proven and the implementation is straightforward. t step is the tying together of this capability with meteorological information coming ground-sounding stations and sensor-equipped balloons, buoys, and other platforms.

or step in the development of a global earth survey system is the extension of the vations to include the surface of the land and oceans, as well as the atmosphere. bility and experimental value have been demonstrated in aircraft simulation and manned mission experiments. An ability to monitor thematically the status and changing features land and sea on a rapidly repeating cycle and for indefinite periods is achievable within to five years. This capability would result in geologic photomaps of continent-sized for geological resource studies with the basic information being obtained by radar-equipped aft and by satellites employing electronic-return imagery (e.g., TV) or possibly film return. a capability would also provide thematic imagery for land use maps, indirect crop yield ates, and area measurements of water, snow, ice, vegetation types, and continuing ys of urban areas, cultural features, and transportation nets. It is expected that the al monitoring capabilities of the experimental Earth Resources Technology Satellite, duled for initial flight in 1972, will provide data with ground resolution on the order 00 to 600 feet, with significant improvements coming over the next few years. At the time, precise altimeters and other space-based instruments can provide a preliminary surement and monitoring capability for sea characteristics.

Understanding. The significance of developing models of dynamic phenomena is that model represents the level of understanding necessary to provide assurance that predictions be accurate, that the effects of decisions can be tested in advance, and that progress ard integrated systems is feasible. Even taken alone, this level of scientific understanding he interactions of the environment would represent a new plateau of knowledge.

order to model the dynamics of earth, understand earth tides, measure polar motion in real e, and define the real shape of the sea, there must be an earth reference system that does assume fixed earth points or a stationary earth center of mass. A new world reference tem reflecting the real earth rather than a hypothetical static earth will permit measurement to 100 times more precise than possible today. The possibility of earthquake prediction, tually "error-free" space tracking, and scientific earth modelling all depend upon such an dated reference. Economic values in the areas of navigation, ocean exploitation, and rtography are foreseen but cannot be quantified at this time.

eight to twelve years it is expected that a number of comprehensive physical models could developed. Included would be models of the atmosphere, the dynamic earth, sea surface temperature, and spectral characteristics of numerous crops and vegetative cover for varying seasonal conditions. The models would be computerized and the data from the observational system would be fed to the computer so as to provide a continuous description and predictive capability of the physical system involved. Current activities include studies of small-scale problems subject to modelling (e.g., Columbia River basin regional water management).

	IMMEDIATE	NEXT	FUTURE
OBSERVATION	Continuous thematic monitoring of the land and sea		Continuing improvement
UNDERSTANDING	Definitive world reference system		Continuing improvement
	Comprehensive models of the atmosphere, dynamic Earth, oceans, and land		Continuing improvement
PREDICTION	14-day weather forecasts and long range climate estimates		Continuing improvement
	Useful forecasts of food production, disasters, and national resources availability		Continuing improvement
MANAGEMENT/MODIFICATION		Regional natural resources management experiments	
		Hemispheric weather modification experiments	

PROJECTED RATE OF ACHIEVEMENT

Prediction. The availability of the global observation data and the associated computational models should allow a systematic prediction in several areas in the 1974-78 time period. In the area of weather forecasting or prediction, the specific goal of accurate 14-day forecasting is considered achievable on a global scale in this time period. Substantial benefits will accrue from such a capability. For example:

- Advance warning of natural disasters (e.g., more effective storm and flood warning).
- More productive construction (e.g., optimum scheduling of the work force, materials, and equipment at construction sites).
- More efficient agriculture (e.g., savings from unnecessary reseeding, irrigating, fertilizing or spraying operations, or from improved timing of hay, grain, or fruit harvests).
- More efficient management of the routing and scheduling of air, highway, and water traffic.
- Decreased spoilage of perishable commodities in transit or at terminal facilities.

ile weather forecasting is projected to be available on a global basis with a 14-day lead e in the 1974-78 time period, it is expected that somewhat more modest forecasting of th resources and associated geophysical processes will be available in this time period. ne examples of these forecasts and an indication of how benefits will accrue are as follows:

- Sea temperature predictions coupled with appropriate communications will be used for the planning of fishing operations.

- Sea state predictions will further enhance the usefulness of weather predictions in ship routings.

- Crop yield predictions will enhance the planning for distribution and marketing of food products.

- Forage availability estimates will help grazing planning.

- Prediction of water run-off, based in part on snow measurements, will improve flood control.

Management. The major benefits of an earth survey system will ultimately be derived n our ability to utilize the information and predictions for the most efficient modification our environment and management of our resources. In the 1978-82 time period, preliminary os should have been taken in this area. It is expected that initial hemispheric scale weather dification experiments will be carried out during this time. Such experiments will be a essary step in learning how to manage the total climatic environment. In the area of water ources, a demonstrative experiment might be conducted based on the predicted availability vater in a given region, the prediction being based, in part, on the extent and content of changing snow cover. The experiment could take the form of planning the allocation of er between irrigation and electric power usages based on predictions derived in large asure from space observations.

jectives

attacking the dual problem of understanding the natural environment and of applying that wledge to the better management of human affairs, the programmatic activities of NASA ak down into three related but currently separate activities: Earth Physics, Meteorology, Earth Resources Surveys. The objectives of each of these activities are selected steps ard the broad goal of developing and applying aerospace technology for the benefit of nkind; at the same time they represent direct contributions to positions of value achievable ing the next decade and a half.

Earth Physics. The recent and current focus of this discipline has been the National odetic Satellite Program (NGSP), in which NASA provides the satellites and the Defense partment, the Coast and Geodetic Survey, and other institutions make observations and asurements from ground-based instrumentation. The key data being sought are a geometric gravitational description of the whole earth that will permit accurate positioning of face features in relation to each other and an understanding of the gravity field's effect orbiting bodies. The future focus of the activity will be to expand and refine our descriptive capability in a set of sequential steps in order to provide, first, a new world reference and second, an effective model of the solid but active earth. One of our broad objectives, then, is to:

1 - Provide a precise and accurate geometric description of the earth's surface.

This implies, first, meeting the NGSP commitment of developing a unified world datum based on observations of the Geos class of satellites. Extension of this geodetic control to the coastal and, eventually, deep ocean areas would imply developing more precise measurements, probably based on laser tracking, to overcome the problem of unstable seaborne platforms. Another aspect of earth geometry is the need to derive very accurate relative positions of tracking stations, especially for deep-space and planetary missions where precise trajectories must be achieved through midcourse and terminal corrections. The more immediate specific objectives therefore are to:

- By 1972, develop a Unified World Datum (UWD) accurate to $\pm$ 10 meters in an earth-centered coordinate system, including all major datum blocks.

- As a contribution to ocean exploration and survey, develop space techniques to extend geodetic control, with an accuracy of $\pm$ 10 meters, to the continental shelf and deep ocean areas.

- Locate earth satellite tracking stations within $\pm$ 5 meters with respect to each other on the UWD.

- By mid-1971, position deep space tracking stations on the earth's surface to within $\pm$ 0.5 meter with respect to the earth's spin axis and to within $\pm$ 1 meter in absolute longitude.

Another broad objective is to:

2 - Provide a precise and accurate mathematical description of the earth's gravitational field.

This objective, taken together with the preceding one, implies the development of a first-order static model of the earth. Since the gravitational field is not uniform, it is necessary first to "map" it; this can be done by ground observation of the orbital perturbations of satellites. An accurate description of the gravitational field can be used to predict satellite positions up to 24 hours in advance. Such information would reduce tracking requirements of satellites in orbit and would permit better interpretation of scientific data that are sensitive to knowing the instrument location in space. The specific objectives currently being pursued are to:

- By 1972, provide a mathematical description of the earth's gravitational field by means of an expansion to the 15th order and degree of the spherical harmonic coefficient with an overall accuracy of $\pm$ 3 mgal.

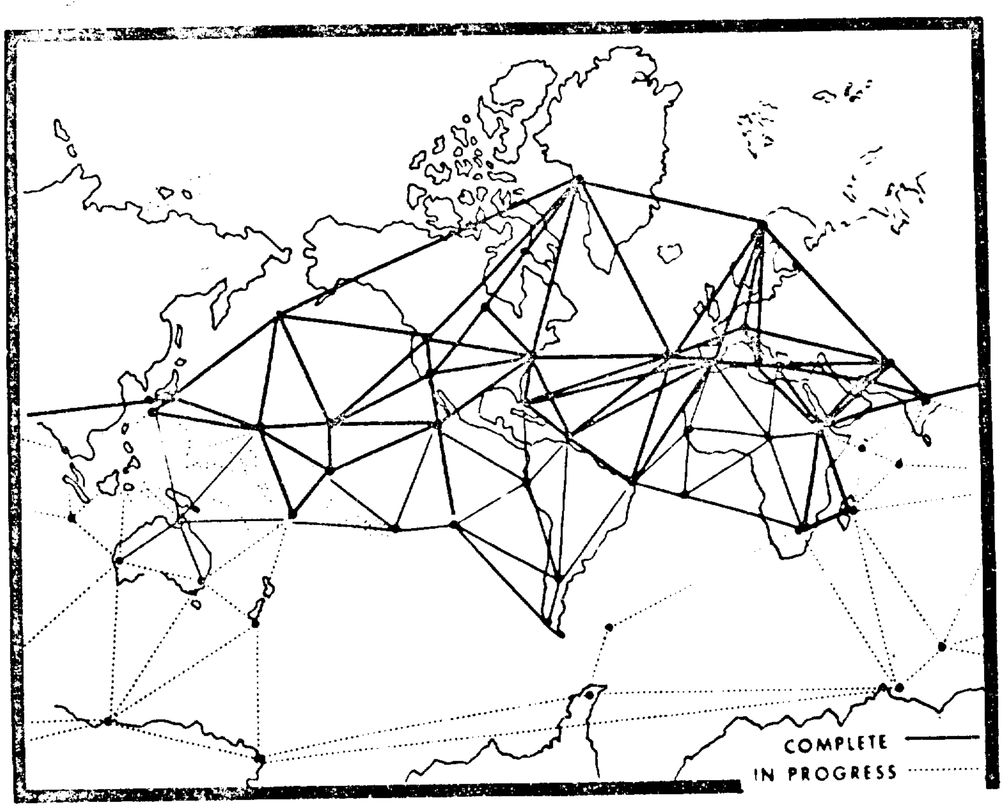
- Test the available earth gravitational models (e.g., Smithsonian Astrophysical Observatory - 1966 Model, Naval Weapons Laboratory Models 9 and 5E) for adequacy in satellite prediction computations.

last broad objective in Earth Physics contains the major elements of future program activity:

3 - Determine time variations of the geometry of the ocean surface, the solid earth, the gravity field, and other geophysical parameters.

s objective implies an extension from the static, or time-invariant, earth model mentioned lier to a true model of the active earth. The oceans are known to have "highs" and "lows," l to "tilt" from one coast to another. At the same time, the actual ocean surface is in con-it tidal motion, as is the "solid" earth. In addition, the continents appear to be drifting wly relative to the earth's mantle, and slow shifts occur along geological faults. The motion the poles and the relationship of this motion to earthquakes has not been fully investigated. means for attacking these and related questions include drag-free satellites, precise satellite imeters, ground-based observations of the moon and radio stars, and the development of math-atical techniques and concepts for developing dynamic models of the earth. Some of the ecific objectives are to:

- Demonstrate the feasibility of satellite radar altimetry to determine the distance from the ocean's surface to the earth's center.
- Develop the overall systems capability to use satellite altimetry to determine the mean height variations of the ocean's surface to ± 1 meter.
- Develop the space techniques to measure the earth's rotational period in Universal Time to an accuracy of one part in 10^9 and to measure motions of earth's spin axis (pole) to within ± 0.2 meter.
- Develop space techniques for measurement of earth surface motions of ± 10 cm.



UNIFIED WORLD DATUM

Meteorology. The NASA Meteorology program began in 1959 with the transfer of the Tiros project from the Department of Defense. Tiros televised the first pictures of the earth's cloud cover from above the atmosphere in 1960; improved versions have been developed and have been the basis of the ESSA operational meteorological satellite system since 1966. ESSA satellites now routinely provide global weather pictures every day, and automatic readout of local cloud photography is provided continuously to ground stations all over the world. NASA improves, builds, and launches these operational satellites for the Department of Commerce. Continuing research in meteorology from space is supported by sounding rockets and NASA research and development satellites. One of these is Nimbus, a large stabilized medium-altitude observatory carrying a variety of measuring instruments. Another is the Applications Technology Satellite, a high altitude platform from which the weather activity over the entire sunlit half of the earth can be observed in near-real time. The NASA Meteorology Program has two parallel lines of activity. One is research in instrumentation and systems that can lead to a scientific understanding of the total weather process, and the other is development and test of systems for operational use by meteorologists in forecasting and, eventually, modifying weather conditions. These activities lead to the first major objective which is:

1 - Observe on a global scale the composition, structure and energetics of the atmosphere to understand atmospheric interactions: (1) within the atmosphere; (2) in response to solar inputs; and (3) at the air-earth surface interface; and establish a basis for experiments in control of the weather.

The end sought is a working knowledge of how the weather is affected by external and internal forces so that an accurate model can be developed. Continued refinement of the level of understanding based on greater precision and sophistication of observation and measurement techniques is implied. Not until an acceptable world weather model has been developed can the first basic experiments in large-scale weather modification and climate control be considered. The level of scientific understanding sought in considering such modelling is illustrated by the following specific objective:

- Conduct atmosphere measurements on a global scale to establish quantitative models of atmospheric structure, composition, and physical and chemical processes, including energy transfer by means of radiation, convection, and the fluxes of latent and sensible heat and of potential and kinetic energy.

  Global measurements of the following are necessary:

  - Air density ranging in accuracy from ± 0.2 percent near the surface to ± 2 percent at the mesopause.

  - The presence and distribution of such minor constituents as water vapor, ozone, atomic oxygen, and nitric oxide in the stratosphere and mesosphere in mixing ratios of about one part per million.

  - Radiation fluxes (short-wave and long-wave) through the atmosphere to accuracies of ± 1 percent.

- Sea surface temperatures to accuracies of $\pm 1^{\circ}C$.

- Distinction between ice clouds and water clouds.

- The liquid water content of clouds in relative amounts of about 10 steps.

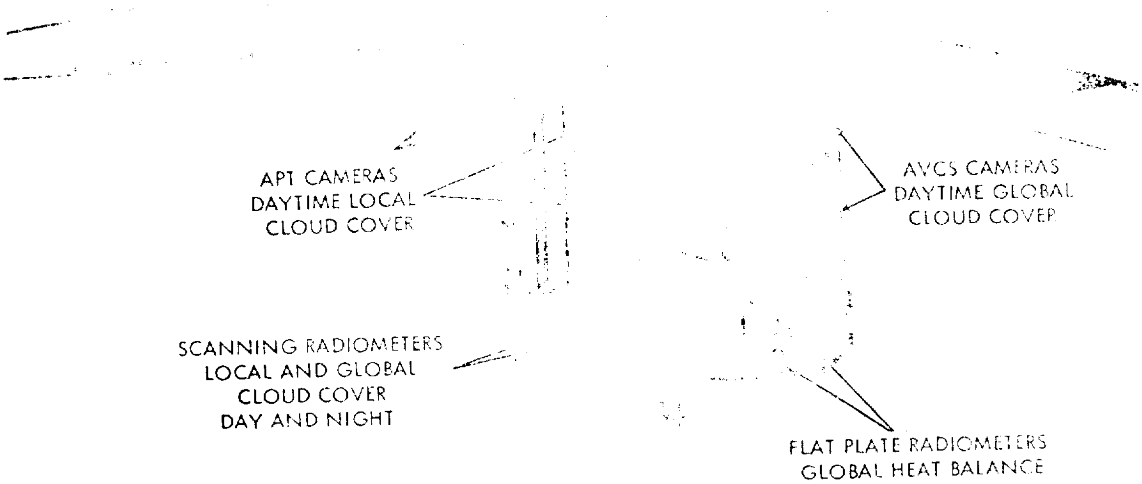
Observation of the following relationships are necessary:

- Between radiation from space and both atmospheric temperature and composition.

- Between sea surface temperature, cloudiness, water vapor distribution, and the windfield.

- Between the sea state and windfield.

- Between the windfields at various levels in the troposphere, stratosphere, and mesosphere.



ADVANCED OPERATIONAL METEOROLOGICAL SATELLITE

The next group of major objectives in the Meteorology Program deals with NASA's responsibilities to the operational aspect of meteorology in terms of instruments and systems for short- and long-term forecasting. These are to:

2 - Develop a remote sensing capability for determining globally the vertical structure of the atmosphere which, when supplemented by conventional observational techniques, will provide the data required for large-scale, long-term weather forecasts.

3 - Develop and establish a system for continuous observation of weather features so that such observations can be applied to short-term weather forecasting.

4 - Continue developmental support to operational meteorological satellite systems.

Taken together, these require a number of specific developments in support of ESSA, first for experimental and then for operational use. The specific objectives are:

- Develop advanced sensors for use near earth and at geostationary altitude to determine atmospheric pressure or density to $\pm$ 0.2 percent. vertical temperature and wind profiles to $\pm 1^{\circ}C$ and $\pm$ 3 meters per second, respectively, and such characteristics as convection, sea state and surface temperature.

- Develop the technology and systems required to support data gathering experiments involved in the Global Atmospheric Research Program (GARP). This requires orbital tests of techniques for measurement of temperature profiles in the troposphere and lower stratosphere and for wind measurements in the lower and upper troposphere.

- Develop a prototype operational geostationary meteorological satellite based on proven technology derived from ATS, Syncom, Nimbus, and Tiros.

- Based on research program observations, apply appropriate temperature sounding instruments to operational meteorological satellites.

The last area of meteorological activity is directed to specific support of space and aeronautical flight activities. Both design and operations of aerospace vehicles today are hampered by the absence of adequate information on the atmospheric forces which interact with the vehicle.

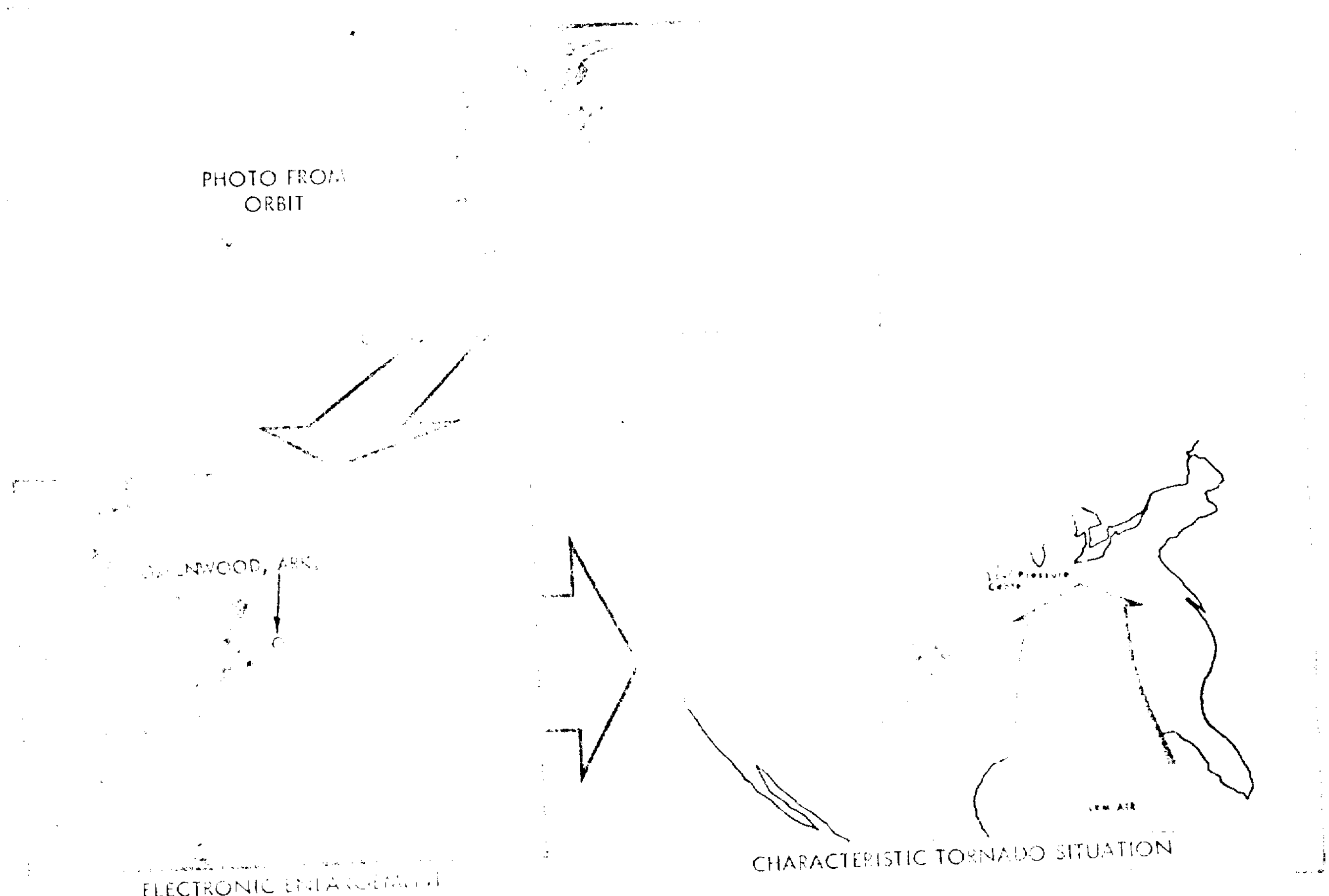
Well-known examples of airplane and space vehicle meteorological problems are the structural loads and guidance and control requirements which arise from the strong and variable winds and shears existing throughout the troposphere; the wind loads induced by both the steady-state and turbulent velocity components while a space vehicle is on the launch pad, particularly while it might be in the unsupported condition just prior to launch; departures in atmospheric

ity, temperature, and pressure from nominal or assumed ... the ... trajectory
he vehicle trajectories; and the possible vehicle disturbances from the ... trajectory
to strong and unexpected winds at staging altitudes. Other meteorological problems also
ognized are electrical discharges which may lead to ignition or explosion of combustibles,
otechnics, or fuels; excessive humidity leading to unexpected moisture absorption and
akdown of insulating materials; and possible airborne salt particles or other corrosive
ments. The reentry trajectory, reentry heating history, and communications during return
nanned or instrumented capsules from space missions are highly dependent on atmospheric
sity. Finally, the impact point and landing and recovery operations are influenced by
ds, sea state and local "weather" conditions. Based on these problems there is an
ective to:

- Develop meteorological technology to support aeronautical and space systems design, testing, and operations.

The specific activity being considered in this area is:

- Develop instruments and techniques that will permit determination of discrete and statistically significant models of winds, temperature, and gusts for high-altitude aircraft and space vehicle design, and to measure small-scale phenomena required for world-wide flight operations.



TORNADO ANALYSIS DERIVED FROM APPLICATIONS TECHNOLOGY SATELLITE

Accuracy of measurements sought are:

Winds: $\pm$ 0.5 meter per second vector error at the surface; $\pm$ 0.5 meter per second vector error averaged over 25-meter layers between 150 meters and 20 kilometers; $\pm$ 3 meters per second vector error averaged over 500-meter layers between 20 and 100 kilometers.

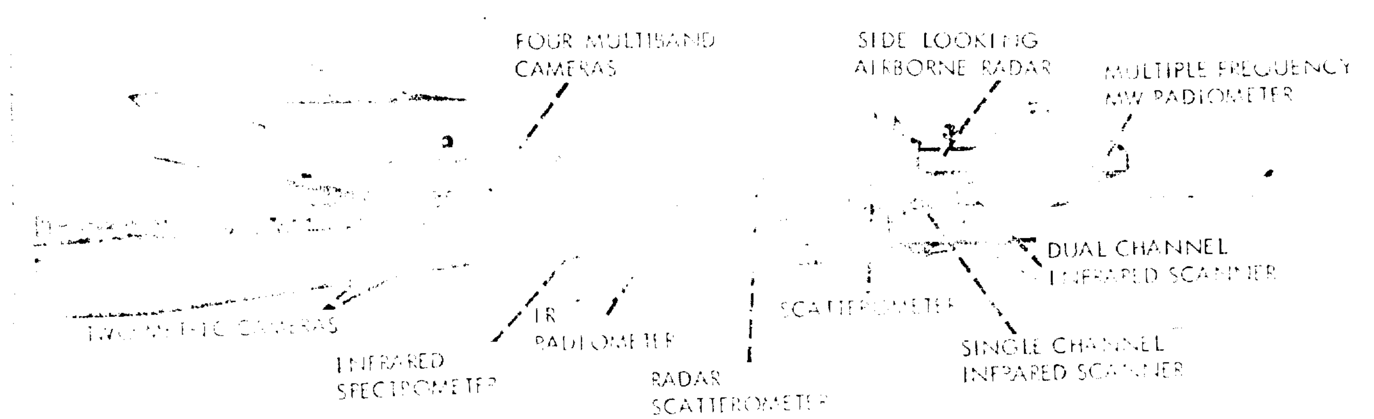
Density: $\pm$ 1 percent up to 30 kilometers and $\pm$ 3 percent between 30 and 100 kilometers.

Temperature: $\pm$ 1°C

Pressure: Consistent with density requirements.

Relative humidity: $\pm$ 5 percent up to 20 kilometers.

Earth Resources Survey. This represents one of the newest space application activities within the Earth Surveys Program. It has evolved as an outgrowth of aircraft remote sensing capabilities long in use by commercial and governmental institutions. By extending the range of sensors to permit observations from space, the area coverage on each pass is vastly increased. Thus, space platforms passing continually over the whole surface of the earth provide a unique opportunity for monitoring surface phenomena. It is felt that, in such areas as forestry, agriculture, geology, geography, oceanology, and hydrology, observations of the earth from space will make significant contributions.



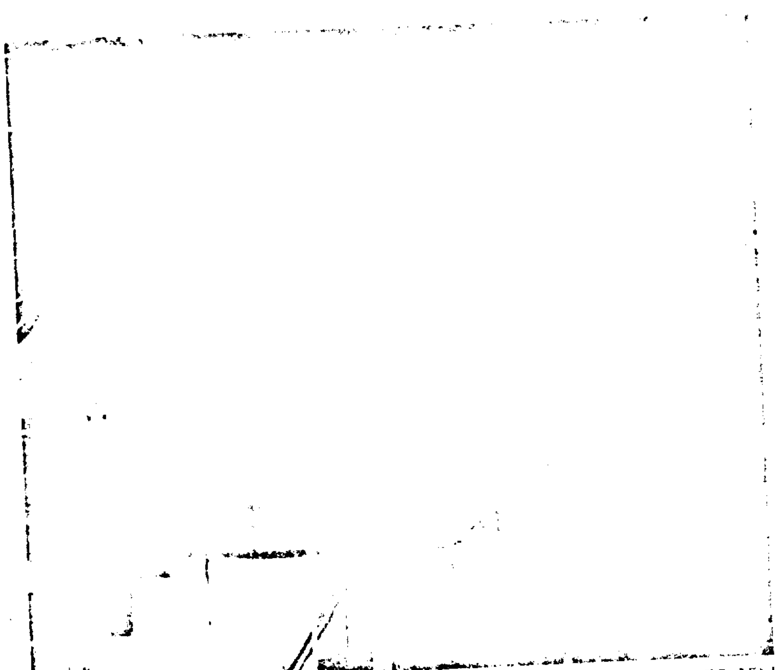
EARTH RESOURCES SURVEY AIRCRAFT

e, NASA has relied largely upon aircraft platforms for sensor testing and signature
mination, with space-acquired data being limited to photographs taken during manned
ons and low-resolution images from sensors on meteorological satellites. The first
ated experimental Earth Resources Survey Technology Satellite (ERTS) is scheduled
in 1972 with a multispectral earth sensing payload. An important aspect of this
am is the emphasis on involving the ultimate users of earth resources data as early as
ble in the research and development phases of the program. Such involvement is
ssary to ensure that the ability to use such space capabilities grows at a rate appropriate
development of the capabilities themselves. Thus, while aimed at eventual operational
s on a par with space meteorology and space communications, the Earth Resources effort
rises a large element of continuing scientific research as well as development. Therefore,
jor objective is to:

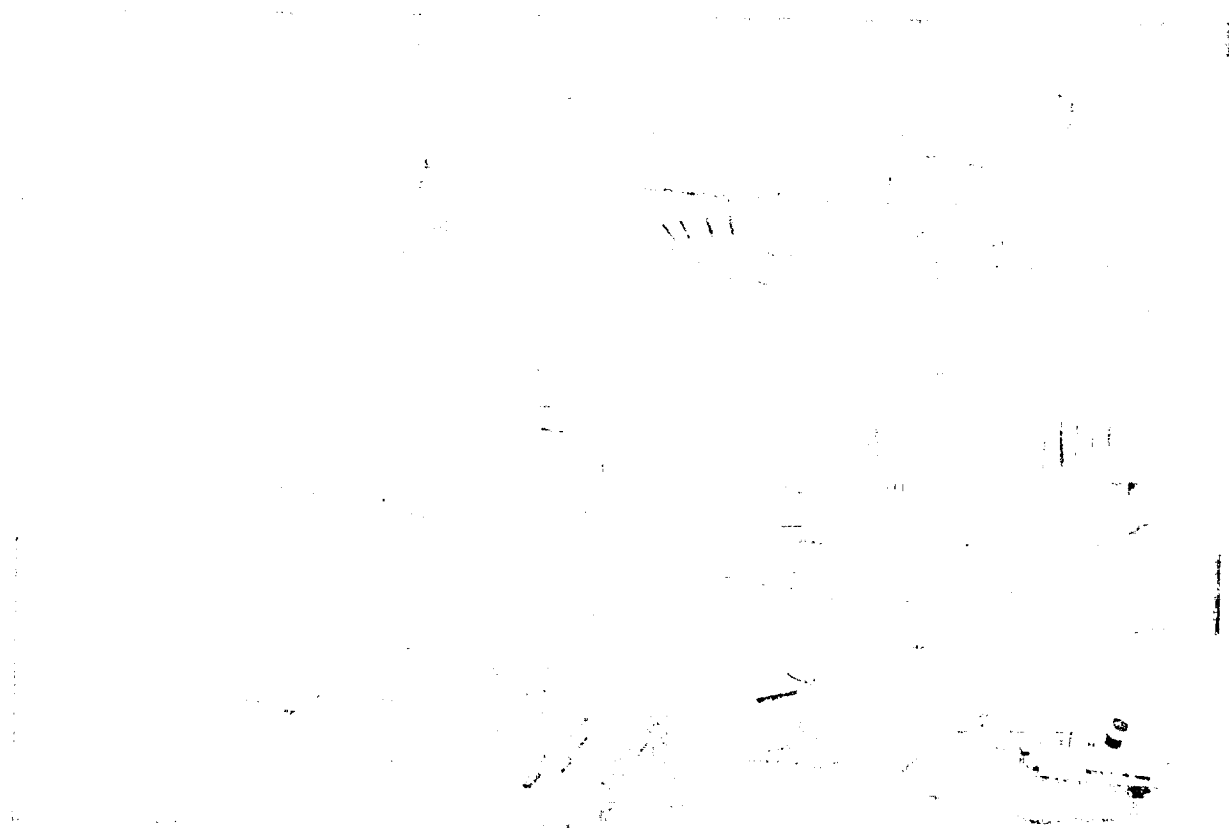
– Determine the performance of remote sensors in identifying earth resources, and establish signature recognition criteria.

represents a continuing effort to understand what surface conditions can be unambiguously
riminated by the various types of remote sensors, considering spatial, spectral, and temporal
ature characteristics. Sensor calibration of this type requires data from space, in addition
easurements in the laboratory, to establish a baseline. Specifically, then, the first steps
to:

- Obtain a multispectral record of earth features from space over a period of several seasons at ground resolutions of 300 to 600 feet.
- Identify the distinguishing spectral, spatial, and temporal characteristics of significant earth features utilizing remote sensing from aircraft, spacecraft, and in the laboratory.



CROP IDENTIFICATION BY REMOTE SENSING



THE ENVIRONMENT OF MAN

The next class of objectives covers that area of work leading toward operational earth survey systems. It is envisioned that future operational systems will make complementary use of spacecraft, aircraft, and ground-based sensors. The spacecraft in an operational system could range from small, single-purpose spacecraft to very complex multifunctional systems incorporating meteorological and other disciplinary instruments. Nevertheless, it is too early to define the character of an earth survey system and its operational satellites at this time. It is hoped that the early experimental ERTS missions will provide data of direct utility to several users, although it is likely that many potential high return applications will also require data from instrumented aircraft and ground sensors. For example, a major source of environmental information will probably be unattended ground-based sensors such as stream flow and ocean temperature gauges that can be interrogated by satellites. The next steps in moving toward operational systems are, therefore, to:

2 - Develop sensors, subsystems, and experimental spacecraft for application to future operational earth survey systems.

The specific areas that can be attacked now within this framework are to:

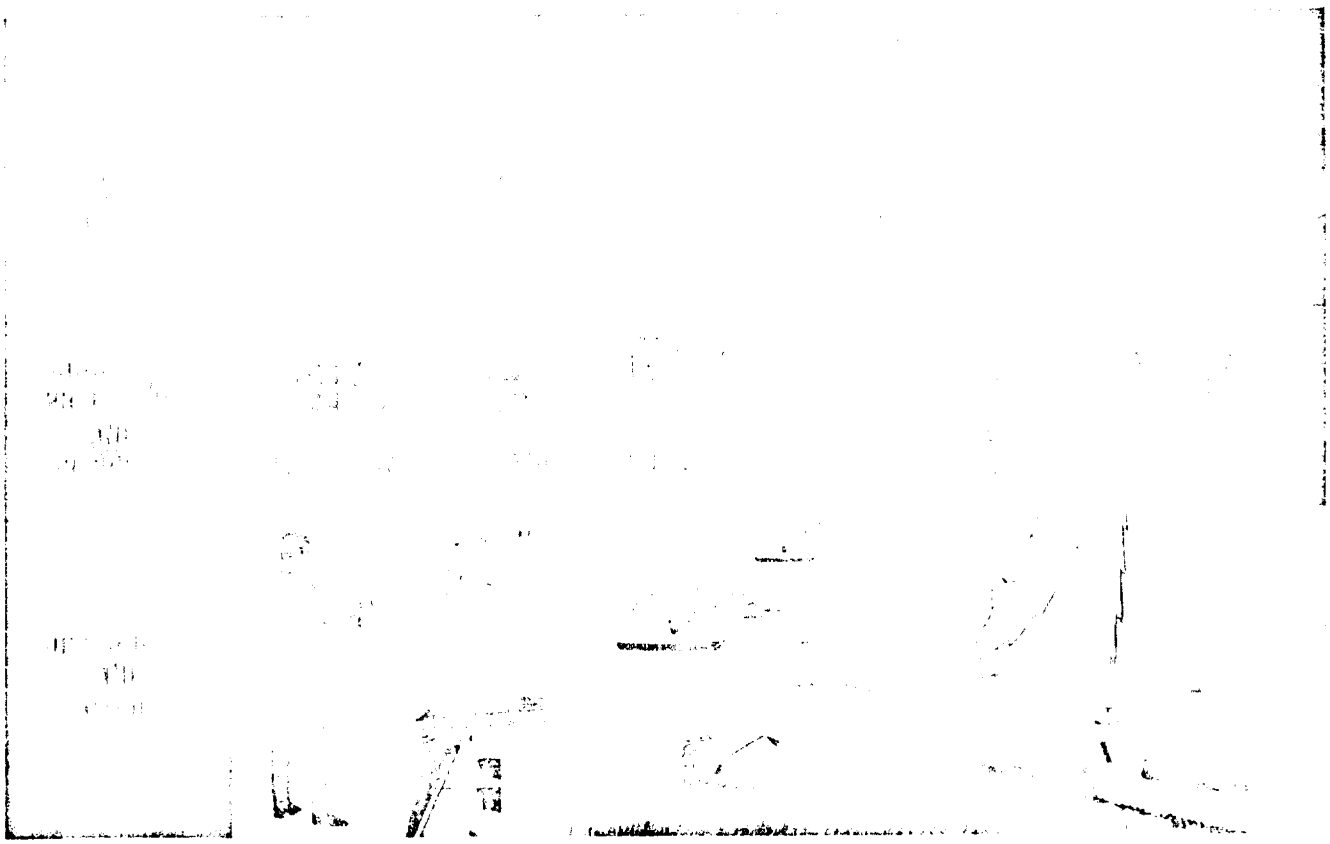
- Define the characteristics and capabilities of earth resources satellites that will follow the early ERTS missions.

- Develop operational prototypes of space-qualified remote sensors, including active and passive microwave and thermal infrared imagers.

- Develop operational prototypes of remote sensors to be utilized on aircraft.

- Develop methods for using data collected from earth-based platforms.

- Determine the manner in which manned space systems can be utilized effectively for earth resources survey work.



SPACE AIDS TO SOLUTION OF ENVIRONMENTAL PROBLEMS

Looking further into the future, it is clear that the satellite, aircraft, and ground-sensor systems represent only one element in a very complex structure of data gathering and information distribution functions. There must be a careful assessment and trade-off evaluation made between the cost and productivity of each part of the total system, reflecting an understanding of the alternatives available. At the same time, since space platforms are considered to be a necessary part of eventual operational systems, it is clear that the amount of data that can be accumulated is very large; its translation into useful information and subsequent timely dissemination to those who need it to make informed decisions represents a major area of research and development activity. Two significant objectives, therefore, are to:

3 - Determine the capabilities, characteristics, and elements of an operational user-oriented earth resources survey system including ground, airborne, and space components.

4 - Evolve a complete da[illegible] [illegible]em from the acquisition of remote sensor data to its eventual applic[illegible] by a user to a specific problem; develop techniques and formats for data h[illegible]ing and utilization.

Specific activities can be undertaken now within the state of current knowledge and using data from current programs. These first steps condition the rate at which the remainder can be pursued, especially in the area of data handling and information distribution. As the next steps, then, it is important to:

- Determine the relative capabilities of remote sensing from aircraft and spacecraft.

- Make comparative estimates of expected benefits and costs for spacecraft-assisted, aircraft-assisted, and integrated earth resources information systems.

- Conduct data utilization experiments (e.g., for land use classification, and for snow cover/water run-off and ocean-temperature/fishing correlations) employing observations from earth resources spacecraft, advanced meteorological satellites, and manned space flight missions.

- Assist user agencies in the development of acceptable and effective user decision models.

- Develop a data processing and distribution system adequate for the conduct of initial data utilization experiments.

- Develop an advanced data system capable of on-board data recognition and compression and including possible use of data relay satellites for transmission of earth resources data.

COMMUNICATIONS AND NAV

munications and Navigation are two very important lifelines of civilization. Over the rs, man has found it necessary to continually improve and increase the capacity of both tions to meet the needs of travel and commerce. Improvement of capabilities in these areas received growing emphasis during the past half century with the rapid increase in commerce veen ocean-separated continents. Hard lines for communication, expensively maintained, e become saturated. Present-day navigational aids cannot meet all-weather, high accuracy uirements of heavy traffic on the sea and in the air.

space program has provided methods for expanding and improving national and international nmunications. Primary effort has been directed toward improvement of point-to-point nmunication with passive and active satellite techniques. Passive systems were investigated launching Echo I in 1960 and Echo II in 1964. Active system development began in 1962 h the launching of the low orbiting Telstar and Relay, which proved the feasibility of using ive communication satellites. A base for present-day commercial space communications was ablished in 1963 by launching Syncom into a synchronous orbit. Since then, Comsat Corpora- n and the Department of Defense have placed several satellites into synchronous and near- chronous orbits for operational use.

Navigation, two concepts involving different capabilities of space systems have been studied. e results of these studies have indicated the feasibility of utilizing satellites to provide proved navigation. In addition, experiments have been flight tested on several of the plications Technology Satellites, the results of which will be most useful in the design of an perimental navigation satellite. The Department of Defense Transit satellite system has monstrated feasibility of satellite navigation systems, although Transit is a highly specialized stem.

e current program includes satellites to test and demonstrate technology applicable to mmunications, space broadcasting, data relay, data collection, and navigation and traffic ntrol. The primary research and development effort utilizes the Applications Technology tellite in synchronous orbit. This work also involves development of spacecraft subsystems pecially tailored for application satellite requirements. The program includes the improve- ent of frequency utilization by investigating the potential of using other frequency bands and investigating means for reducing interference. Based on information developed from this ogram, consultation is provided to meet national and international needs.

oals

/ith these program activities as a point of departure, the following goals have been established or communications, navigation, and traffic control:

- To facilitate the application of satellite and space technology to communications needs, nationally and internationally, and to the need for data collection from earth-bound, airborne, and space vehicles.

- To facilitate the application of satellite systems and space technology for the improvement of terrestrial, air, and space vehicle navigation and traffic control.

Possible Future Achievements

It is technically feasible for the Nation through aggressive pursuit of the above goals to achieve by the mid-1980's widespread routine use of satellites to provide the following communications and navigation services:

- Good quality, dependable, flexible communications from anywhere on land, at sea, in air, or in space to any part of the earth.

- The capability for communication with the entire population of large areas for purposes of educational, informational, cultural, and other national purposes.

- Efficient collection of data from and the tracking of earth based, airborne, or space vehicles.

- Safer and more comfortable air and sea travel by providing an improved navigation and traffic surveillance capability, along with the ability to communicate environmental information and forecasts while en route.

Two sets of values result from these achievements. One is a set of broad and general benefits; the other set of values is related more directly to the individual services provided.

The broad and general benefits that will result from these achievements are:

- The promotion of United States leadership and prestige through new and improved communications and navigation capabilities by generating international cooperative programs, demonstrating the practical use of space for the benefit of mankind, and establishing frequency allocations and system standards.

- An improvement of the United States balance of payments posture by creating new foreign markets for United States equipment used for fixed, mobile, aeronautical, and maritime space applications; minimizing or eliminating the need for foreign sites to provide space communication and tracking support; and developing a demand for consultation and training by United States industrial firms.

- Improved domestic communications for commerce, education, and entertainment; increased safety through improved navigation and traffic control; and more and better resource knowledge gained from collection of resource data not now available.

The specific benefits that can be realized from the projected communications achievements include:

- Using broadcast satellites, education can be accelerated by transmitting courses, not otherwise available, to rural and other sparsely populated areas. Shortages of teachers with particular skills could also be alleviated and unique teachings of specific professors could be made widely available.

- More rapid and effective communications could be provided to accelerate industrialization of less developed countries and to reduce their dependence on foreign communication "hubs," thus providing them with a greater degree of independence.

- Entertainment, news, and advice during emergencies can be provided to remote areas by broadcast satellites. This type of service would also be available to separated segments of the populace of underdeveloped countries.

- Libraries and other centers of knowledge could be made widely accessible via satellite communications. Thus, the resources, capabilities, and expertise of such institutions could be made available for entire populations to use and enjoy.

In the area of Navigation and Traffic Control, the following benefits can be realized:

- Operating costs of commercial transportation systems can be reduced due to improved efficiency of operations through more direct routing and higher density traffic patterns. Also, property and equipment losses can be avoided by using satellite position-fixes and satellite observation data to avoid storm areas and aircraft or ship collisions. This latter benefit also adds to the comfort and safety of the passengers aboard the commercial carriers.

- The higher traffic density permitted through the use of a navigation satellite system would permit substantially more traffic to use existing oceanic shipping and air lanes. The increases in traffic thus permitted would forestall the need to establish and use longer oceanic lanes to accommodate projected future increases in traffic.

- In case of accidents in oceanic or other remote areas, search and rescue activities can be carried on more effectively and emergency aid provided more quickly through the use of a satellite system that can accurately pinpoint accident locations and provide effective communications with them.

Benefits which can accrue through use of a Data Relay system are:

- Reductions could be made in data acquisition and tracking costs by closing or reducing operation of present tracking and data acquisition stations. There would also be a reduced need for constructing and operating new ground stations to meet future requirements for Tracking and Data Acquisition (T&DA) coverage. A prime example would be full-orbit T&DA support for a manned polar orbit mission.

- Continuous contact could be maintained with spacecraft. Some missions today, due to the particular orbit and limited number of ground stations, are in contact as little as 20 percent of the time. Control of spacecraft such as the Orbiting Astronomical Observatory could be lost by a break in continuous tracking.

- Increases in data readout capability would be possible. Present data readout capability is limited by the data storage capacity on the spacecraft and by the limited capability of certain ground stations to handle very rapid readout of data while the satellite is within view.

- Tracking accuracy would be improved because of the nearly continuous information available on the satellite's orbit.

- There could be concomitant reductions in cost and increases in lifetime of satellite systems. Not only could recorders be eliminated from satellites, thus reducing costs and increasing payload; but by elimination of such equipment a spacecraft would not become disabled by a recorder failure as is the case today.

ose benefits that can be realized from a space system for collecting data are:

- The ability to gather data leading to: New and better global models of the earth's environment; better knowledge on migration of wildlife; better information on hydrological conditions such as water and/or snow level.

- The ability to reduce data acquisition costs and time. Methods currently used include the employment of many men to visit and record conditions at particular remote locations which results in manpower costs requires a considerable amount of time.

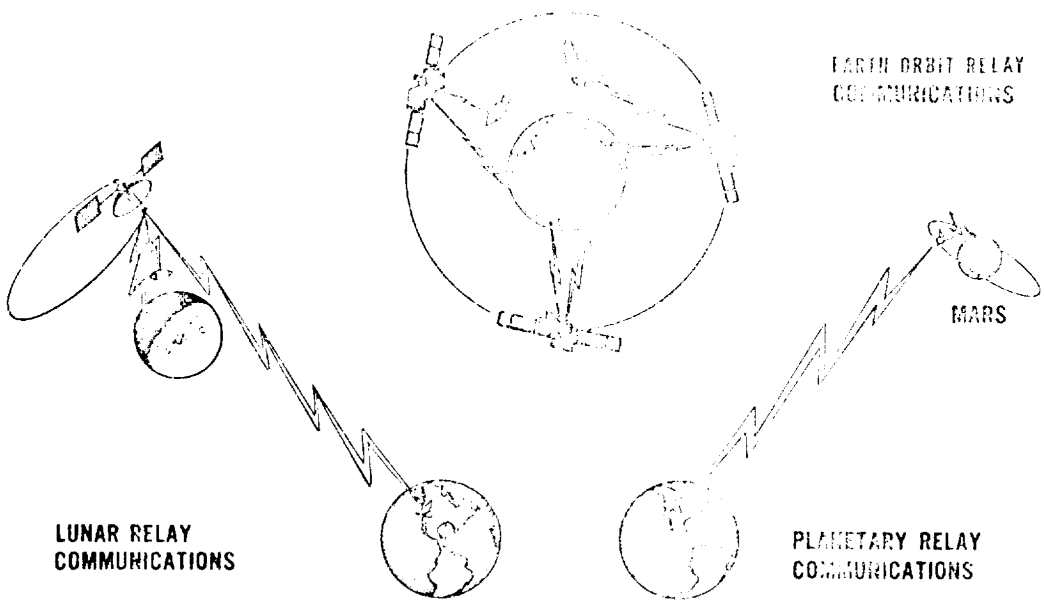
<u>ojectives</u>

order to realize these benefits, specific technology must be developed. Users must learn to apt to a vast enhancement of data, long desired and now available. Also, the data handling d operating characteristics of the system must be such that they permit a smooth integration h communication and navigation systems currently in use.

ese and other significant factors have led to four broad objectives:

l – To develop and demonstrate satellite systems and spacecraft technology applicable to space communications needs.

s objective implies a broad and diversified spectrum of spacecraft and systems developments meet needs in areas such as space broadcasting, fulfilling special educational and informa-nal needs, providing a data relay and tracking function for other space missions, and applying



CONCEPTS OF FUTURE USES FOR DATA RELAY SATELLITES

satellites to the collection of data from fixed and moving platforms. Such systems will involve the development of technology required to perform these services via satellites, the analysis of cost-benefits derived from the use of the satellite service, and analysis of the interface between the satellite system and the conventional ground system performing similar services. NASA's role in these different applications will vary depending on the requirements, capabilities, and management roles of the users.

Based on particular communication applications, the following specific objectives have been established:

- Develop technology for both a flexible demand assignment multiple access system and a random access system aimed at data collection.
- Develop the application of space technology to meet unique educational and informational needs of individual professions and public services.
- Develop the space technology of high radio-frequency power output for the educational/instructional broadcast application.
- Develop the space technology for the controlled illumination of desired areas of the earth (to provide space antennas with shaped patterns, e.g., major beam dimensions of up to 7 degrees and minor beam dimensions as small as 1/10th degree).
- Develop analytical models to define the electromagnetic environment and perform experiments to measure indigenous noise affecting design of satellite systems.
- Develop technology for generating and pointing multiple independent beams of RF energy from spacecraft.

- Develop the capability to establish an independent world-wide tracking and data acquisition satellite system to support near-earth satellite missions.

- Determine the feasibility, practicability, and desirability of using satellites to assist in tracking and data acquisition for lunar missions and planetary missions.

- Develop the technology for maximizing the communication use of the synchronous orbit.

- Develop satellite systems for the collection of data from a variety of fixed and moving sensors contributing to terrestrial and environmental observation and measurement.

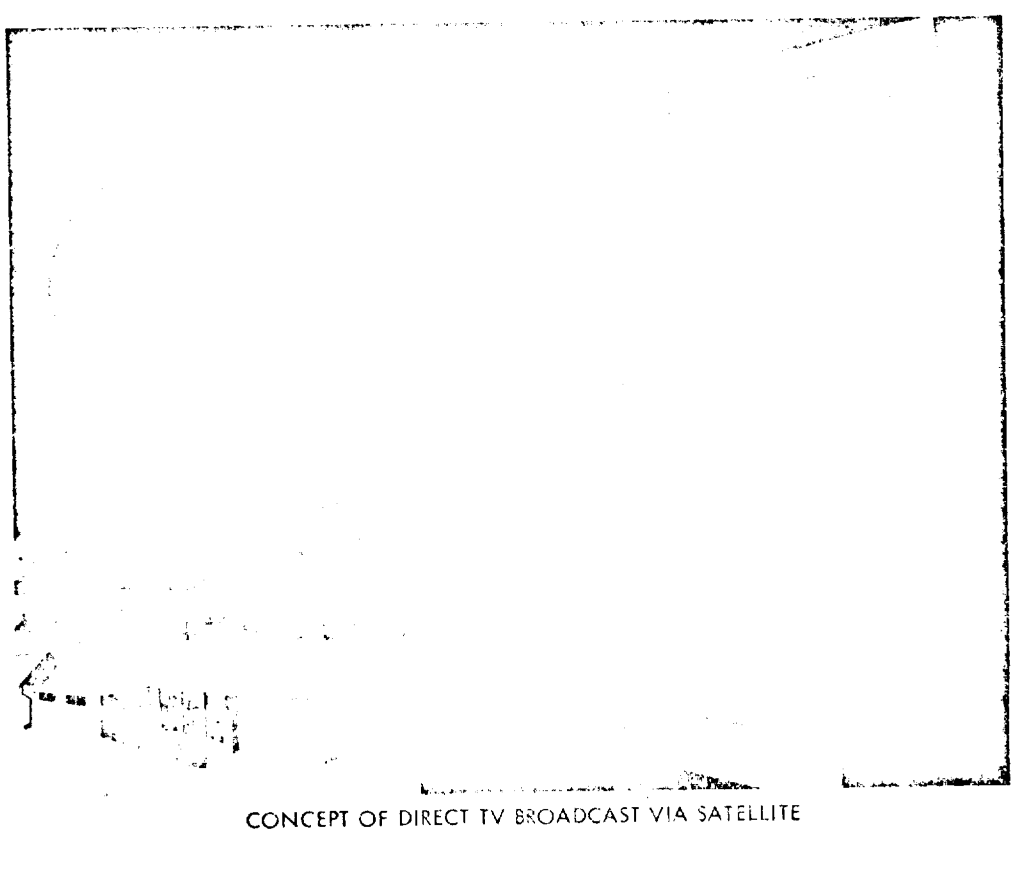
th ship and airplane traffic has increased considerably during the last decade. The require-
nts for control and direction of this traffic have increased accordingly. Such traffic over
ean routes experience difficulty due to the inaccuracies in present-day navigation and
sition fixing techniques. The situation in the future will become more aggravated since
eable increases in traffic are predicted for the future. Consequently, the growing need for
curate position fixing of aircraft and ships; which is necessary for safety, proper routing, and
st-benefits; leads to the next broad objective:

2 - Develop and demonstrate satellite systems and spacecraft technology applicable to space navigation and traffic control needs.

REQUIREMENTS OF NAVIGATION/TRAFFIC CONTROL SATELLITE SYSTEM

This broad objective implies a program of developing spacecraft and systems technology to accommodate a number of different requirements leading to improved navigation and traffic control. The systems must be capable of allowing navigators of the vehicles to calculate their own courses and positions as well as transmit this information to control centers on the ground. It is also necessary that the system provide information to the navigators on storms and ocean surface conditions of importance. The specific objectives necessary to meet these requirements are:

- Determine the utility of satellite systems to meet the oceanic aircraft and ship navigation and traffic control needs.
- Develop satellite navigation techniques which can fix the position of aircraft and ships to 0.5 nautical mile.
- Provide a navigation accuracy to over-ocean aircraft which will allow maximum lateral separation as low as 30 nautical miles.
- Determine the effect of propagation anomalies (i.e., multipath reflection) on the accuracy of satellite navigation systems.
- Develop satellite-aided aircraft collision avoidance concepts.
- Develop aircraft and ship to satellite automatic digital data transfer concepts.
- Provide technology leading to navigation and traffic control equipment that is of low cost to the user.



CONCEPT OF DIRECT TV BROADCAST VIA SATELLITE s these systems become operational in the future, they will further crowd the radio transmission ands. The next broad objective is directed toward alleviating this problem through more effi-ient frequency utilization:

3 - Determine optimum use of the electromagnetic spectrum for communications and navigation satellite systems. In particular, determine the statistical variation in electromagnetic propagation through the earth's atmosphere at all potentially useful wavelengths.

he significant problem here is that the frequency band now assigned to communications with nd control of spacecraft will soon be full. We must therefore examine transmission character-stics in other transmission bands that might provide satisfactory service. Meanwhile, the mprovement in efficiency of present-day service and the reduction of interference associated with such service should be investigated. Also, the practicability of sharing frequencies between pace and terrestrial services should be studied further. Accordingly, the following specific objectives have been established.

- Define the absorption, scattering, refractive, and noise characteristics of the atmosphere and near-earth space over the frequency range 4 to 100 GHz. and 0.56 to 10.6 microns.

- Assess the use of and develop space and ground technology for millimeter-wave satellite communications systems.

- Assess the use of and develop technology for laser satellite communications systems.

- Investigate radio frequency interference between satellite systems, and between satellite and terrestrial systems sharing the same frequencies, and the influence of propagation mechanisms on such interference.

As more and more space applications systems become operational and more users are involved, NASA must act as the space communications and navigation consultant to government and industry. This consultation activity is identified as the following broad objective:

4 - Fulfill NASA's role as space communications and navigation consultant to government and industry.

NASA's responsibilities as an advisor to other government agencies are growing in step with the increase in space applications in these areas. To perform this function effectively for each Agency, we must maintain an understanding of the continued technology advances in this area and the new capabilities offered by such advances. It is only by this means that we can advise others on the most effective manner or possible alternatives to satisfy given requirements. Accordingly, the specific objectives which relate to consultation are as follows:

- Define the considerations affecting satellite spacing in the geosynchronous orbit.

- Define the considerations affecting frequency allocations for space applications.

- Perform on a continuing basis studies and analyses necessary for NASA to fulfill its responsibilities to advise the FCC and other government agencies concerning technical characteristics and desirability of communications and navigation satellite systems.

  Assist in the preparation of technical documentation for national and international organizations concerned with space frequency allocations.

SPACE TECHNOLOGY

Space technology is the development of that body of knowledge and experience that enables the Nation to undertake and accomplish new space missions. Such new knowledge and experience are prerequisities for present and planned activities described in other space program categories. The following are a few illustrative examples of how space technology contributed to and was utilized in developing many important elements of our manned space flight vehicles:

- Building of the Saturn V was based on a large body of missile and propulsion technology. From the missile buildup of the 1950's came the 250,000-pound thrust oxygen-JP engines and from these came the development of the 1.5 million-pound thrust F-1 engine. From hydrogen-oxygen research in the 1950's came the 15,000-pound thrust RL-10 and 200,000-pound thrust J-2 engines for upper stage propulsion.

- Building of the Apollo spacecraft was based on the technology of the Mercury and Gemini spacecraft. The configurations of all stemmed from the blunt body entry concept of Allen in the early 1950's and subsequent research on entry heating and ablation materials.

Goal

These examples remind us of the large body of knowledge accumulated from diverse sources over a long period of time that is utilized for specific space developments. Such new developments, which will lead to future accomplishments in space, are dependent on technology advances resulting from continued research activity. Thus, the goal of Space Technology is:

- To advance fundamental knowledge pertinent to space flight, to provide the technical capability for undertaking future missions, and to expand the usefulness and reduce the cost of space operations.

Possible Future Achievements

Pursuit of this goal will lead to the following technological achievements:

- Establishment of a technology base enabling the conduct of future missions that best serve the national interest.

- Establishing a base of technology that is relevant to national security.

- Establishing a base of technology, for activities not related to aerospace, that would increase the Nation's capability to undertake new public works and services and would stimulate innovations in the private sector.

The values associated with the above achievements do not come from development of the technology itself but from its application to specific developments. In the space program, the values are therefore reflected in new mission and operating capabilities developed in each program area.

Once a specific element of technology has been brought to a useful point there are generally many applications for it. Typical examples are space vehicle guidance and control, propulsion, electric power, structures, and communications and instrumentation. The application of these technologies becomes part of the development program where the technology is tailored to the mission. The capabilities that result from such new technology are therefore also reflected in the various program areas.

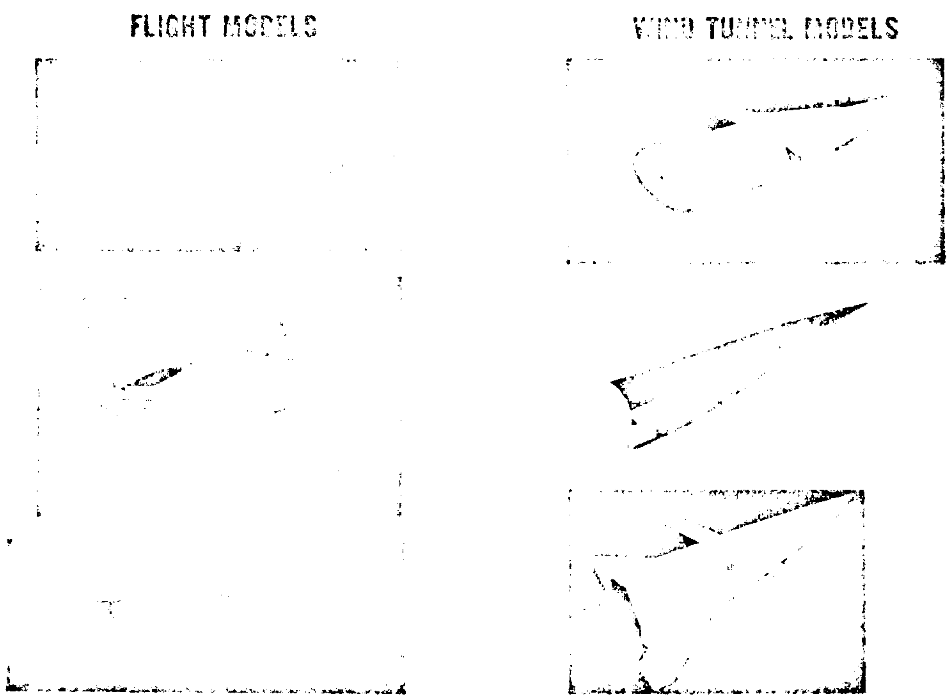
Objectives

The broad and specific objectives, which have been developed for technology, cover a wide spectrum. The first of these objectives is:

1 - To advance the technology for leaving and entering the atmospheres of and landing on various planetary bodies, including earth.

Accomplishment of this objective will require the development of new concepts and materials, testing of the concepts in ground-based facilities, and demonstration of some in flight. Some of the specific objectives that will lead to the achievement of this broad objective are:

- To establish technology for low-cost refurbishable or replaceable heat shields; to determine radiation characteristics of super alloys and coated refractories for reusable heat shields on earth entry vehicles.



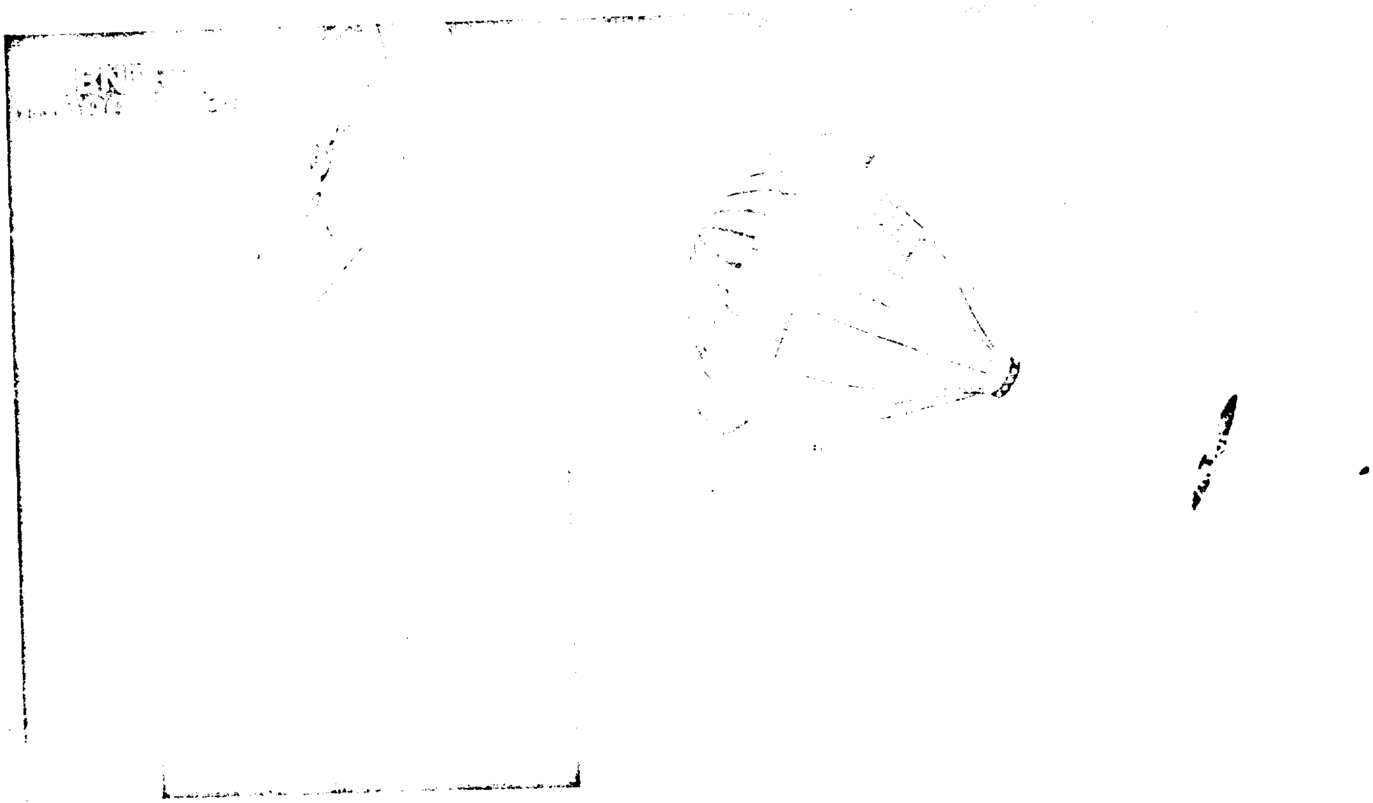
EXAMPLES OF LIFTING ENTRY VEHICLE RESEARCH

- To establish vertical take-off and horizontal landing characteristics of lifting bodies, to investigate variable geometry lifting entry configurations with auxiliary devices; to experiment with flexible wing and rotor descent systems; and to determine the feasibility of vertical take-off, and horizontal landing for reusable earth entry vehicles.

- To investigate planetary descent systems, including a Mach No. 3 parachute, a Mach No. 4-4.5 decelerator, flexible wings, and rotors for Mars atmospheric entry; to study non-equilibrium radiation and heat shields for entry into the atmospheres of Venus and Jupiter.

- To determine loads and heating of launch vehicles ascending through the atmosphere, including exhaust plume radiation, flame scaling, base flow fields, and aerodynamic loads.

- To develop the aerothermodynamic and heat protection technology required for the design of spacecraft to survive entry into the earth's atmosphere on return from planetary missions.



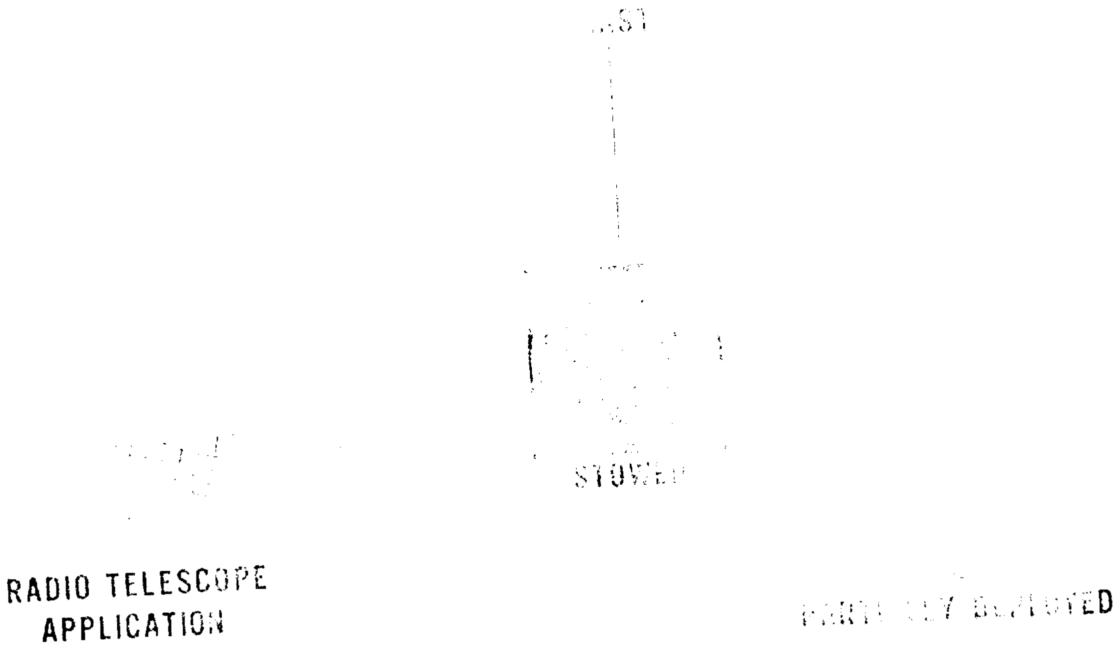
SYSTEM FOR ENTRY INTO MARS ATMOSPHERE

As we move toward the larger and more complex space vehicles of the future there is a growing need for the development of new structural concepts and new materials. Technology needs in this area lead to the following broad objective:

2 - To advance the technology of light weight structures, the knowledge in the materials sciences, the use of new materials, the understanding of the dynamics of complex structures, and the understanding of interactions of space systems with their operating environment.

This broad objective requires work to be performed on such things as air leakage, expandable structures, insulation, meteoroid bumpers, and the development of new materials. Some of the specific objectives that focus this activity are:

- To advance the understanding of the fundamental properties of the solid state with principal emphasis on quantitative relationships between electronic, atomic, molecular, and macroscopic structures of materials and their physical, chemical, and mechanical properties.
- To support basic research on engineering materials of interest to space systems, including the behavior and properties of metals, ceramics, polymers, and composites.
- To study the composition and possible utilization of extraterrestrial materials.
- To investigate new concepts of forming and processing of materials on earth and in space.
- To develop the technology for lunar shelters.
- To determine the characteristics of structures for orbiting radio telescopes having a diameter of a mile or greater.
- To establish technology for storage of liquid hydrogen in space.
- To develop the technology for effective temperature control of long-life, complex spacecraft operating in all portions of the solar system.
- To determine the sources of self contamination of spacecraft and to reduce to a level where it will not interfere with in-space optical observations.
- To provide design criteria for protection of space vehicles against meteoroid damage in the near-earth and asteroid belt regions and on lunar and planetary surfaces.



CONCEPT OF LIGHT WEIGHT DEPLOYABLE STRUCTURE

Present-day automated spacecraft derive their electrical power from the sun and manned spacecraft use fuel cells to generate electric power. However, power requirements of future space systems will far exceed those of our spacecraft to date. These additional requirements will be in terms of increased power, lifetimes of several years, and high efficiency. Research is therefore necessary to extend the capabilities of our present-day methods of electric power generation and also to develop new electric power generation techniques. The need for this technology thus leads to the following broad objective:

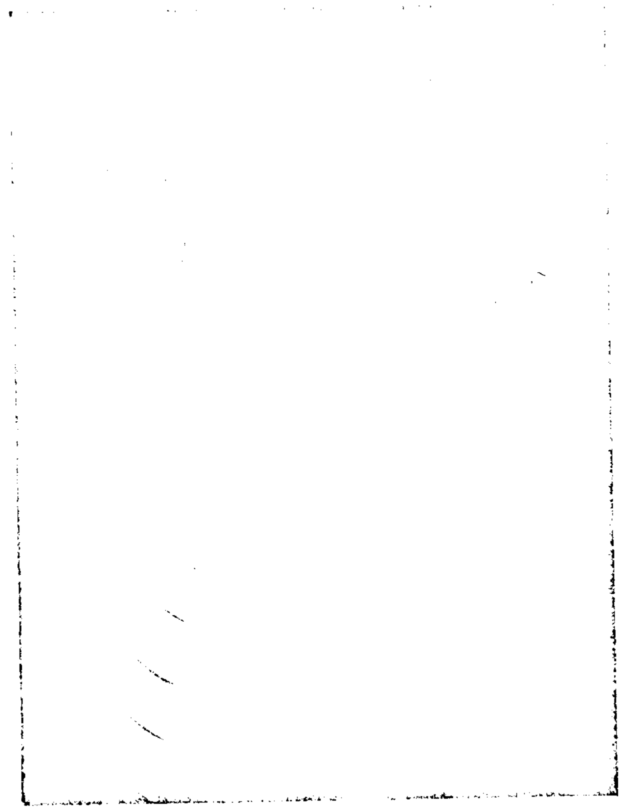
3 - To develop technology and system capabilities for efficient generation and distribution of the required levels of electrical power in the various regions of space and on the surface of the moon and planets.

In achieving this broad objective, it will be necessary to identify ways to extend the capabilities of present methods and to develop new techniques and concepts for electrical power generation. To prove-out the results of this research, proof-of-concept programs must then be conducted on the more promising approaches. The following specific objectives include both the initial research and the later proof-of-concept activities:

- To provide the technology for nuclear electric power generation systems, including isotope thermoelectric, isotope Brayton cycle, Rankine cycle (SNAP-8), advanced Rankine cycle, thermionic, and magnetohydrodynamic.

- To obtain the technology for chemical and electro-chemical power generation and storage devices with emphasis on fuel cells and secondary batteries.

- To develop the capability of providing solar electric power generation over a range of power levels, temperature, and radiator environments and to investigate concepts for very large area and low-cost systems.



CONCEPT OF HIGH PRESSURE CHEMICAL ROCKET ENGINE

As the concepts of future space activity become more clearly defined, more stringent requirements will be placed on the propulsion systems. These requirements will be in terms of increased performance, operating flexibility, and reliability, thus leading to the broad objective:

4 - To advance the capability of launch vehicles and space propulsion systems in terms of performance, operational effectiveness, and reliability.

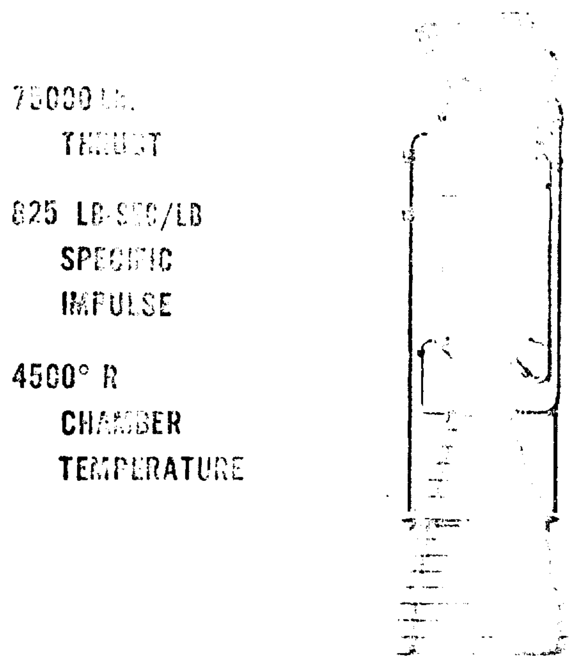
The broad objective of launch vehicles and space propulsion embraces chemical, nuclear, and electric propulsion; each of which requires proof-of-concept programs. The following specific objectives must be achieved to support the broad objective, and of these reusability is one of the most intriguing for the future:

- To develop a reusable nuclear propulsion stage, using the 75-thousand-pound thrust flight-type Nerva engine now in development, having the capability to serve a number of propulsion applications in space.

- To examine advanced nuclear propulsion concepts having specific impulses greater than 1000 seconds, such as the gaseous core reactor.

- To provide the chemical propulsion technology for low-cost expendable and reusable launch vehicles for small, intermediate size (100,000 pound class) and large size (250,000 pound class) payloads.

- To provide the technology for spacecraft chemical propulsion systems to meet a variety of mission needs, including high energy propellants, high specific thrust levels, a space storable capability, a multiple start capability, and variable thrust.
- To provide electric thruster systems technology for auxiliary and primary spacecraft propulsion.



NERVA NUCLEAR ROCKET ENGINE

Electronic systems will continue to play a major role in space vehicles of the future. Thus, as the capability requirements for future missions increase there will be an accompanying need for further advances in electronic components and systems. This need leads to the following broad objective:

5 - To advance the technology of electronic components and systems and to utilize this technology to provide effective means for: sensing of physical and biological phenomena; handling of information - including discrimination, processing, storage and transmission; improving guidance, navigation, stabilization, and control of spacecraft; and developing long-life and low cost of electronic systems.

The impact of achieving the broad objective in electronics will reach into almost every facet of the space program. Specific objectives which will lead to achievement of this broad objective are as follows:

- Instrumentation: To develop solid state imaging devices having resolutions in excess of 1000 lines per inch (comparable to present-day photographic and TV tube performance) as a means for improving the reliability and versatility of sensors used in space science and application missions. To extend the spectral range of available sensors into the X-ray, UV, and far IR regions in support of earth surveys and astronomical missions.

- Data processing: To develop technology for high capacity (10^8 - 10^9 bits) random-access, on-board memories suitable for use in manned and unmanned earth orbital missions where large quantities of data or complex instructions must be stored for short periods of time. To develop the technology for bulk storage memories of 10^{12} bits which would be compatible with high resolution, video data requirements for both on-board and ground-based data systems. To develop data compression techniques which will permit on-board processing and extraction of critical data for transmission to earth during planetary mission operations.

- Communications: To develop antennas, transmitters, receiving elements, and coding techniques for high capacity (10^8 bits/sec), reliable communication links between orbital or planetary spacecraft and ground stations. To develop millimeter wavelength components for communication through entry or reentry plasmas.

- Optical technology: To develop technology and test techniques for achieving large (3-5 meter), diffraction-limited telescopes suitable for astronomical observations in the space environment. To develop components and evaluate operational concepts for optical communication links between spacecraft and earth, as well as between craft in space.

- Guidance: To develop inertial sensors and systems (gyros, accelerometers, and platforms) for long duration manned missions and logistics vehicles where long life and reduced costs are essential. To develop techniques and components for planetary approach guidance to achieve accuracies of $\pm$ 10 to 20 km which would be compatible with landing, orbiting, or planetary swingby maneuvers.

- Attitude control: To develop precise, long-life control systems and components which can provide platform stability on the order of tenths of an arc second and pointing accuracies of thousandths of an arc second compatible with requirements for large astronomical telescopes. To develop techniques for the effective control of large, flexible structures such as radiotelescope antennas and multi-element space stations.

- Component technology: To develop electronic components of minimum size, weight, and power consumption to enhance payload capability and reduce the power requirements of all types of space missions. To understand mechanisms of failure and from this to develop components with lifetimes in excess of 10 years which would be compatible with long duration outer space missions. To develop high temperature (450°C) components capable of operating in the temperature extremes encountered by near-solar probes or Venus and Mercury landers.

Systems that have a capability to provide life support and useful manual and machine op... s by man in space are a major technology need for long-duration flight. One requirement ...ch long-duration systems is the ability to operate with infrequent resupply. The need for suc... systems leads to the broad objective:

6 - To provide highly reliable, repairable, and long life systems for life support, mobility, and machine assistance for man in space and during extraterrestrial surface operations.

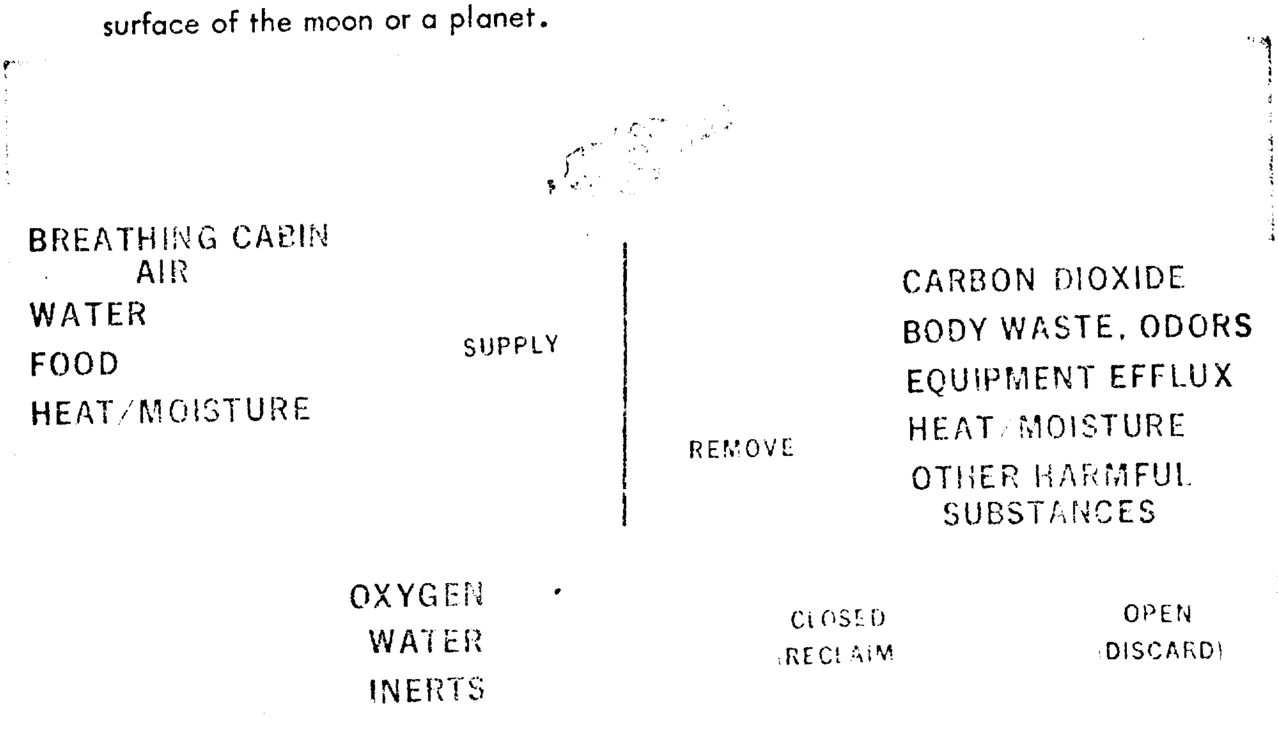
Achievement of this objective deals almost solely with support of man and his functions in space. As such, it is an element of technology that is closely interrelated with similar activity in the area of Space Medicine. The following are the specific objectives that have been identified to achieve the broad objective above:

- To provide the technology for spacecraft systems that supply, process, monitor, and control the composition, pressure, and temperature of atmospheres for maintaining man in space.

- To provide the technology for systems that supply, process, and control water and food for human use in space.

- To provide the technology for systems that remove gaseous, liquid, and solid waste products, that reclaim water, oxygen, and other elements for reuse and that make maximum use of the remaining mass.

- To provide the technology for equipment, mechanisms, tools, and supplies that will enable man to perform assembly and repair functions in space and on the surface of the moon or a planet.



LIFE SUPPORT SYSTEM REQUIREMENTS

The foundation of all space technology rests on the scientific disciplines that provide a fundamental understanding of the processes involved. This leads to the broad objective:

7 - To increase knowledge in the sciences basic to space flight and to extraterrestrial surface operations.

The achievement of this broad objective requires theoretical analyses supported by fundamental laboratory research in the several areas of the sciences that are basic to space flight. Specific objectives that will lead to the achievement of this broad objective are as follows:

- To obtain increased electronic, atomic, and molecular level understanding of the basic properties of matter in the plasma, gaseous, liquid, and solid physical states.

- To conduct basic research on gas dynamic problems relevant to space systems, including gas dynamic lasers, reentry, and internal and external flow.

- To create new and improve existing mathematical techniques, models, and computer programs required for efficient solution of problems in space technology.